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TYPES OF ARTILLERY EQUIPMENT USED BY THE AMERICAN EXPEDITIONARY FORCES IN FRANCE WITH A BRIEF DISCUSSION OF THEIR USES AND THE REASONS FOR THEIR ADOPTION.*

BY

MAJOR GENERAL C. C. WILLIAMS,

Chief of Ordnance, U. S. Army, War Department, Washington, D. C.

1. In a paper necessarily as brief as this, it is possible to do little more than touch upon the principal fundamental reasons leading to the adoption of certain types of artillery for the American Army, and to mention in the briefest possible way examples of the various types.

2. The artillery necessary for the proper equipment of a large field force may be divided into four (4) principal classes:

The First Class consists of the Divisional Artillery which is assigned as an organic part of the Division. These guns are never separated from the Division whatever its mission, except in the direst emergency. In all armies this artillery consists of guns of about 3-inches calibre and howitzers of from 4-inches to 6-inches in calibre. I will in a few moments, explain some of the reasons leading to the diversity of opinion in regard to the calibre of the howitzers.

The Second Class consists of Corps Artillery. This artillery includes a gun of 4.7-inches to 5-inches in calibre and a howitzer about 6-inches in calibre.

* Presented at a meeting of the Mechanical Engineering Section held Thursday evening, February 26, 1920.

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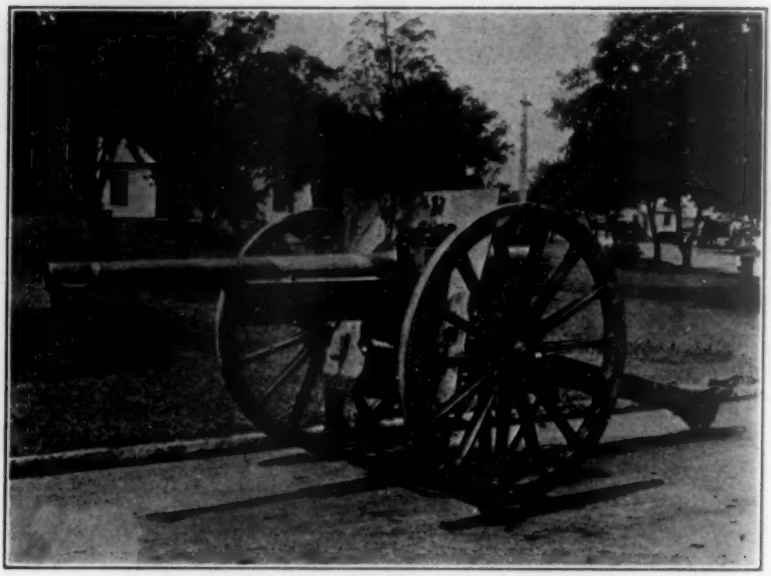
The Third Class is known as Army Artillery and includes a gun of about 6-inches calibre and a howitzer of from 8-inches to 10-inches calibre.

The Fourth Class consists of the Army Reserve Artillery which includes all of the special purpose weapons such as the mountain gun of about 3-inches calibre, the antiaircraft artillery, the very heavy howitzers up to 16-inches in calibre, and the railway artillery for maximum ranges. In addition to this special purpose artillery, the Army Reserve Artillery will include for the purpose of reinforcing weak spots in any given line a certain number of guns of the three first types, namely, Divisional, Corps and Army Artillery.

FIG. 1.



View of the famous French 75-mm. "Soixante Quinze" in firing position.

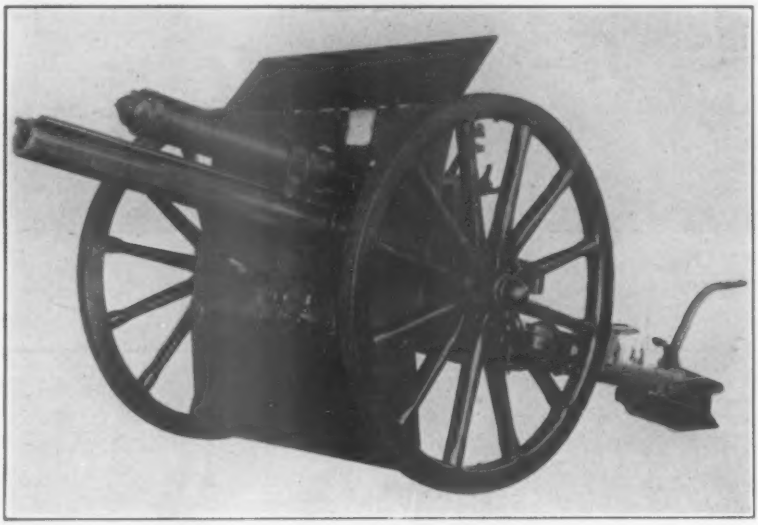
3. Having in mind these four major tactical assignments of artillery we are able to examine the steps taken by the United States to fill the requirements for each class.

4. At our entrance into the War, the United States had available an utterly inconsequential number of field guns; about 750 all-told, ranging from 3-inches to 6-inches in calibre. Our

guns and ammunition were, of course, of distinctively American design and would not interchange with the material used by any of our Allies.

5. The French and British armies were each using artillery equipment of their own design and on our entrance into the War it appeared utterly undesirable to introduce a third series of designs into the general supply service for the three armies. After consideration of this fact, our General Staff decided, in the summer of 1917, that the American Army so far as the

FIG. 2.



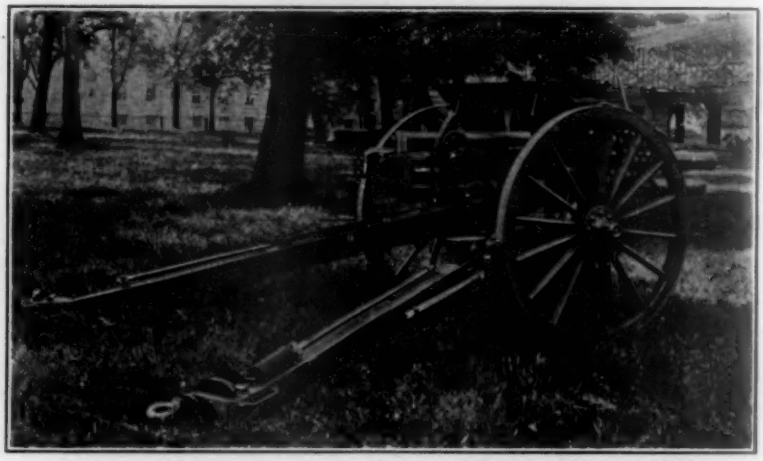
75-mm. gun carriage of the British type. A number of these were manufactured by the Bethlehem Steel Company for both the British and American armies and gave excellent service in the war.

source of its artillery supply was concerned would coöperate with the French, and that our artillery should be as nearly like the French as possible. It was further decided that our artillery ammunition should be completely interchangeable with the French.

6. Following this general policy, by far the greater number of our guns are of French type. We have a few of the British types which were procured for the purpose of utilizing available manufacturing capacity in Great Britain. In general, and for the purpose of facilitating supply, our American types were abandoned.

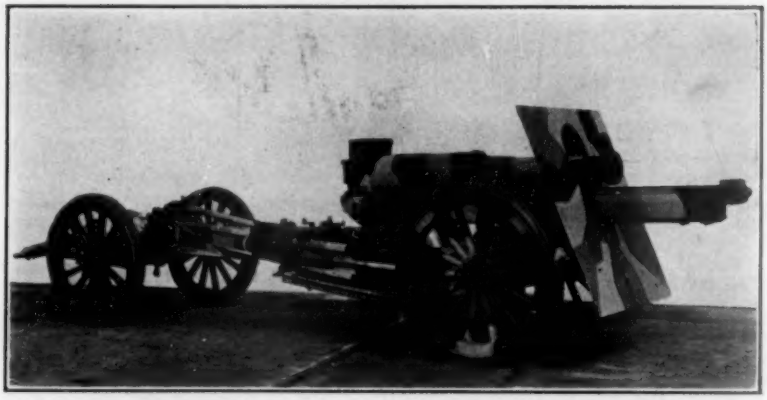
7. To take up in detail the Divisional Artillery—the 75 mm. gun is the principal Divisional weapon. It is the gun which

FIG. 3.



View of the American 75-mm. split trail carriage. A pioneer of this type.

FIG. 4.



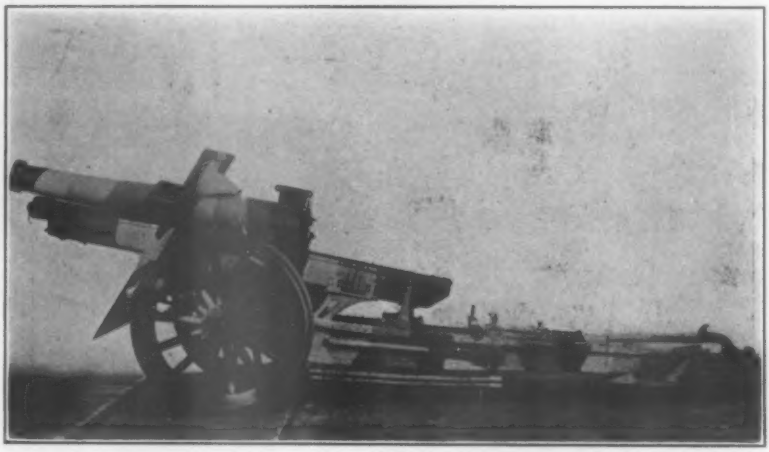
155-mm. Howitzer carriage and limber. This howitzer was very largely used by the American and French armies. About 700 complete units have been completed in the United States. This howitzer was one of the most useful weapons of the war and is credited with having fired the last shot from the American lines against the enemy.

stands closest to the Infantry and is the one whose sole purpose is the destruction of personnel. There are more 75 mm. guns

in an army than all other calibres combined. It is, therefore, the calibre of which we have heard and always will hear the most. We find guns of 75 mm., 3-inch, 77mm. and 3.3-inches in all of the armies. In other words, every country having any experience in war has come to the conclusion that the proper divisional gun is that about 3-inches in calibre and firing a projectile of about 14 to 15 pounds in weight. Some of the reasons for this universal decision are:

First: A gun and carriage of about this calibre, firing a pro-

FIG. 5.



View of the 155-mm. howitzer carriage of the Schneider type.

jectile of about this weight can be readily handled by about six horses.

Second: Projectiles of about this weight are the heaviest that can be handled by one man with any rapidity.

Third: A projectile of this weight is about the smallest that contains a satisfactory bursting charge, and its man-killing characteristics are but little less than are those of projectiles of considerably greater weight.

Fourth: While extremely long range is generally desirable in all guns, it has been found by experience that the Divisional Artillery need fire but few rounds at ranges greater than nine to ten thousand yards. This the 75 mm. gun will do.

8. All of these four reasons which operate to about the same extent in all countries have caused the adoption of this 3-inch calibre gun and this 15-pound shell as the main artillery reliance of the Division.

9. The Divisional gun supplied to the American Expeditionary Forces consisted almost entirely of the 75 mm. French field gun. There were under construction and there would have been issued to troops had the war continued, modifications of the

FIG. 6.

4.7" gun model of 1906. This is an American model of pre-war design and was in use by American troops prior to the Armistice. It is one of the pioneer carriages of the long recoil type.

British and American types of field guns and carriages which would fire the same 75 mm. ammunition.

10. You will have noted that in the four principal general types of artillery there will be found for the Division, for the Corps, and for the Army one calibre of gun and one calibre of howitzer. The historical and textbook description of the difference between a gun and a howitzer states that a gun is a weapon designed to fire at angles of elevation up to about 15 to 20 degrees and that the howitzer is a similar weapon designed to fire at angles of elevation greater than 20 degrees and up to 40 to 60 degrees. As matters stand to-day, however, our new guns

and carriages are all designed to fire at angles of elevation up to and including 65 degrees. A howitzer of a given weight varies from a gun of the same weight and mobility in that it is designed to fire a projectile of about twice the weight at a lower muzzle velocity and at a shorter maximum range. In other words, as the mobility or weight is the governing element in the design of Divisional Artillery we find that for the same weight as the 75 mm. field gun, we can get a howitzer which

FIG. 7.

Rear view of the 4.7" gun model of 1906, showing elevating, traversing and sight mechanisms.

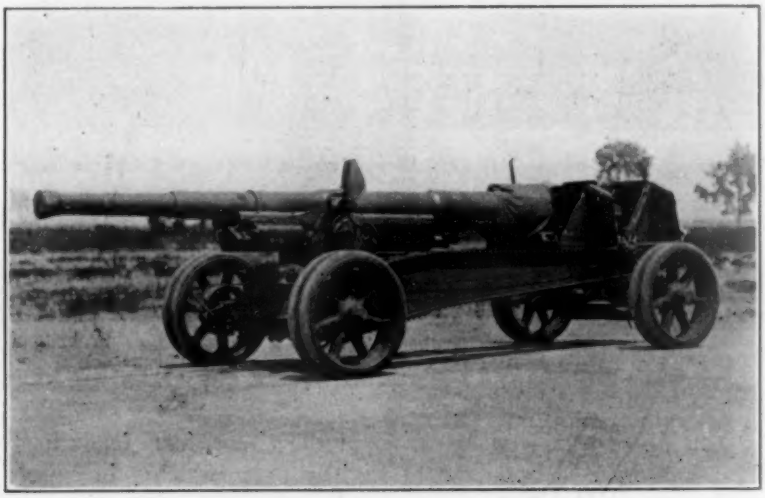
will fire a projectile weighing about twice as much, but we find also that we can get only about 75 to 80 per cent. of the range. The fact, however, that the shells from the howitzer will fall at an angle closer to the vertical than the shells from the guns make the howitzer of great value in searching trenches and thereby reaching the enemy in places where the gun shells would do little damage.

11. Theoretical consideration of the above facts leads us to the adoption of a howitzer of slightly over 4-inches in calibre, firing a projectile of about 30 pounds, as a companion Divisional

FIG. 8.

View in firing position of the 155-mm. "Filloux" gun, which was one of the most useful and efficient pieces of artillery employed in the War by both the French and American armies. It fires a 95-pound projectile over 18,000 yards. Note the wide traverse and high elevation at which gun can be fired.

FIG. 9.



155-mm. "Filloux" gun in the travelling position.

piece to the 75 mm. gun. As a matter of fact, however, our Divisional Artillery was supplied with howitzers of 155 mm. (6-inches) calibre which fired projectiles weighing 90 pounds. The reason for this was that the French Army was already so equipped. The British Army had for this purpose 4.5-inch howitzers and the German, Austrian and Italian Armies had 105 mm. (slightly over 4-inches). There were two schools of thought on this sub-

FIG. 10.

The 8" field howitzer carriage of British design. These howitzers were employed by the British and American armies. Its range is about 11,000 meters. The projectile weighs 290 pounds.

ject in the French Army. One favoring the very light or 105 mm. howitzer and the other favoring the heavier or 155 mm. calibre; but for reasons of production it was finally decided that howitzers of one calibre only could be manufactured in France and despite the much greater weight, and, therefore, loss of mobility the 155 mm. was issued to Divisions. As our Army was to coöperate both in the matter of tactics and supply with the French Army it was thought best to adopt the same calibre. The French Army was being supplied with the Schneider 155 mm.

howitzer of modern design and we decided to issue the same weapon to our troops.

12. The Divisional Artillery of the American Expeditionary Forces was, therefore equipped with 75 mm. field guns and with 155 mm. howitzers.

13. *The Second* principal tactical class is the Corps Artillery. A corps, as you know, consists of two or more divisions together

FIG. 11.

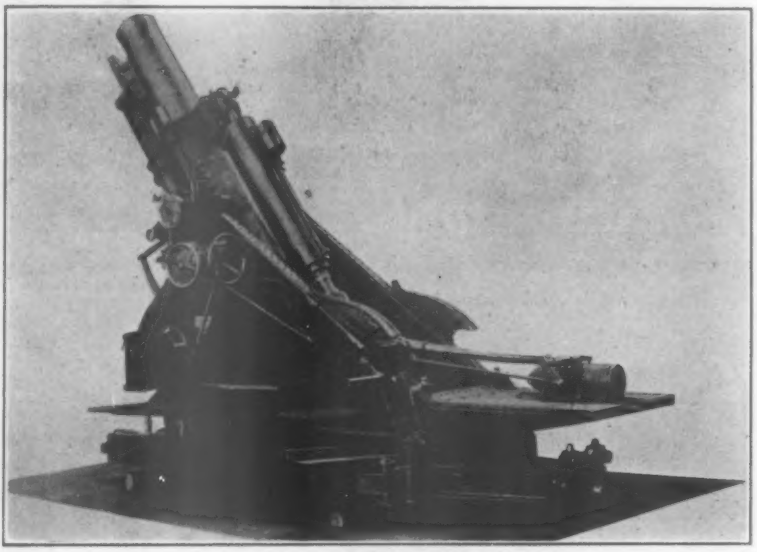
The 9.2 inch howitzer in the loading position.

with a special artillery unit known as the Corps Artillery. As I have stated before the Divisional Artillery has for its principal mission the killing of men. The mission of the corps artillery is not principally the killing of men, but is the destruction of the Divisional Artillery of the opposing army.

14. In order to accomplish its purpose of destroying the enemy Divisional Artillery, it is of course obvious that the Corps Artillery must have greater hitting power, which means shells of greater weight; and it must also have greater range in order that

its men may not themselves be destroyed by the very artillery which it is seeking to annihilate. In addition to these requirements of greater weight of ammunition and greater range the Corps Artillery is required to have a considerable amount of mobility. It need not be moved so readily as the Divisional Artillery, but it must with practically no strengthening of roads, culverts or pontoon bridges be able to be moved anywhere. It must have some ability to go across country.

FIG. 12.

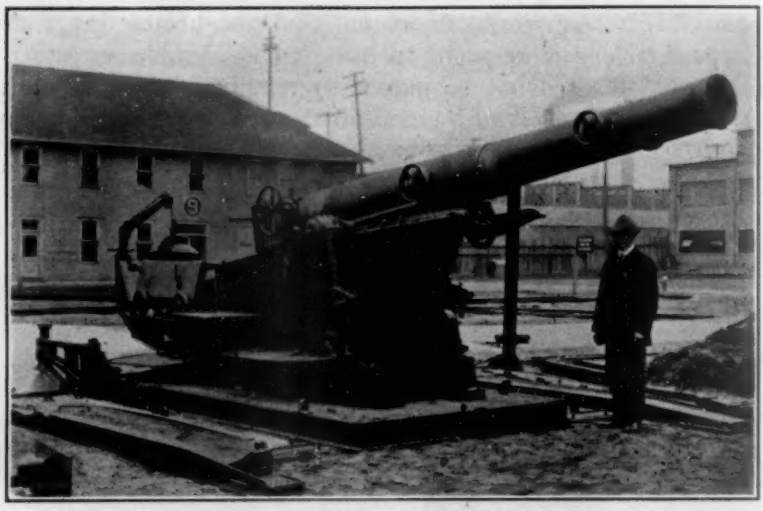


British 9.2" howitzer.

15. All of these considerations led to the adoption of a 4.7-inch calibre for the gun of our Corps Artillery. A careful examination of the situation as to this calibre showed that the 4.7-inch gun of our own standard design was up to the requirements for this purpose and was better suited to the needs of our situation than the British or the French weapons of about the same character. This gun fires a shell weighing 45 pounds.

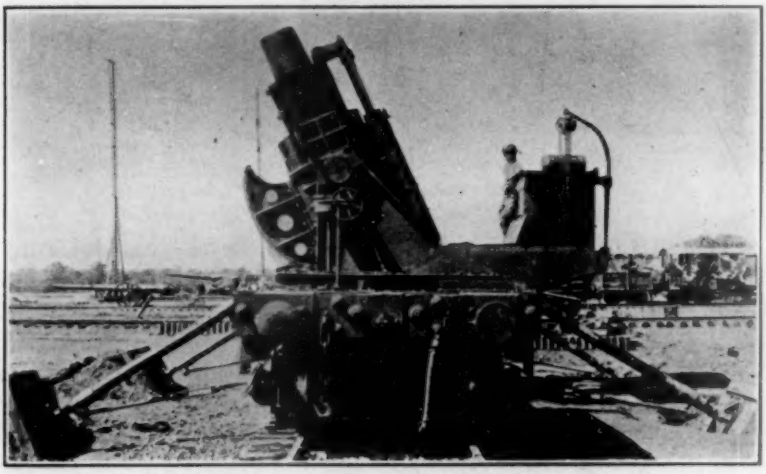
16. For the Corps howitzer, it is universally considered that the 155 mm. (6-inch) calibre is ideal. It has the same mobility as the 4.7-inch gun and fires a 90-pound shell.

FIG. 13.



View of the 240-mm. howitzer and carriage in firing position. This howitzer fires a 356-pound projectile with a range of 17,000 yards. It is the most powerful type of field artillery transported on wheels which was built for the American army.

FIG. 14.



12" mortar railway mount, model of 1918. Range 15,000 yards with 700-pound projectile. Capable of being fired at any angle to the track.

17. As I have stated before, under ideal conditions a lighter howitzer is desirable for use in the Division, but because of limitations in our production program we adopted the view point of the French and issued 155 mm. howitzers to our Divisions and to our Corps. I desire to emphasize particularly the fact that the 155 mm. howitzer is distinctively a Corps weapon and is not one which should normally be issued to Divisions as part of their standard equipment. This is in accord-

FIG. 15.

320-mm. howitzer on French sliding railway mount. A large number of these units were in the hands of the American troops in France.

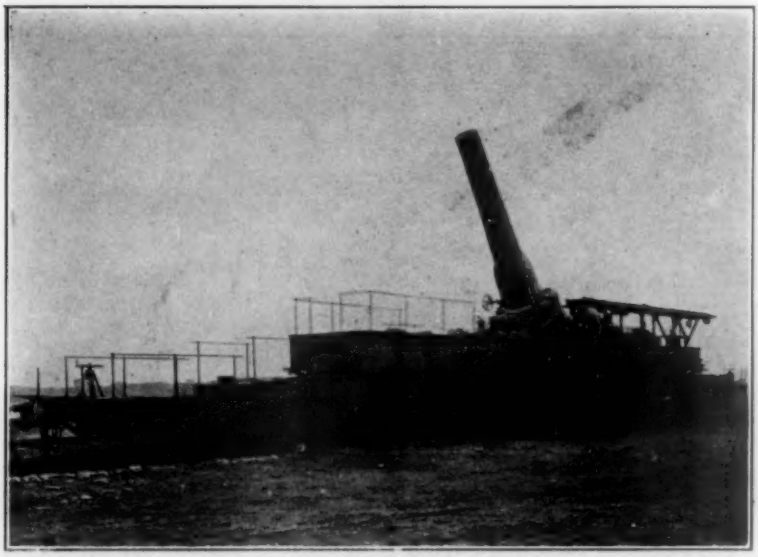
ance with the best Artillery and Ordnance opinion in all countries and was advisedly deviated from in our case, not for tactical reasons but for production reasons.

18. In accordance with the decisions which I have heretofore referred to, some of our Corps were equipped with American 4.7-inch guns, but in most cases our Corps Artillery guns were of the 155 mm. calibre, a gun recognized as being too heavy for normal Corps assignment, but one which had to be used in this case for reasons of production expediency. This gun fires a shell interchangeable with that of the 155 mm. howitzer.

19. *The Third* great sub-division is the Army Artillery. A

field army normally consists of about five corps and it has assigned to it artillery units of greater power and longer range than the Corps Artillery. These guns and howitzers are for the purpose of destroying the enemy Corps Artillery and of interdicting traffic upon roads leading up to the enemy position over which his supplies must come. They should have a normal range for the gun of from 18,000 to 25,000 yards and of the howitzers about 16,000 to 18,000 yards.

FIG. 16.



French 520-mm. howitzer on railway mount. This howitzer throws a 3,000 pound projectile about 20,000 yards.

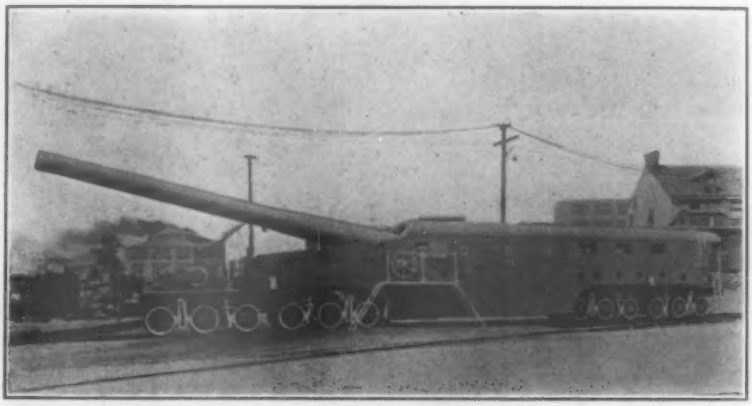
20. During the War, the French had developed a 155 mm. gun known as the Filloux. This gun had the required range and was considered by all to be ideal for the purpose. It was, therefore, adopted for our Army. We considered the British 8-inch howitzer to be the most available companion piece for the 155 mm. Filloux gun. We were able to secure a supply of these howitzers in England, and we therefore, adopted this calibre so that for our Army Artillery we had a 155 mm. French gun firing a 90-pound projectile and an 8-inch British howitzer firing a 200-pound projectile. They were both admirably adapted

to their purpose except that the 8-inch howitzer was of somewhat short maximum range, about 11,000 yards.

21. *For the Fourth* tactical class, namely, the Army Reserve Artillery, the situation was somewhat confused. This Artillery should primarily be of great range and great hitting power. It is for the purpose of destroying bothersome enemy batteries which cannot be reached by corps or army artillery. It is also used for the purpose of bombarding enemy rest camps, supply depots, railroad yards, ammunition dumps and for long range interdiction.

22. The projectiles must be of great destructive power, cap-

FIG. 17.



14" Navy railway mount. Range with 1200-pound projectile 45,000 yards.

able of destroying the most massive field works, concrete dugouts and both semi-permanent and permanent fortifications. These actually used varied in weight from 200 to 3,000 pounds with explosive charges of from 50 to 500 pounds.

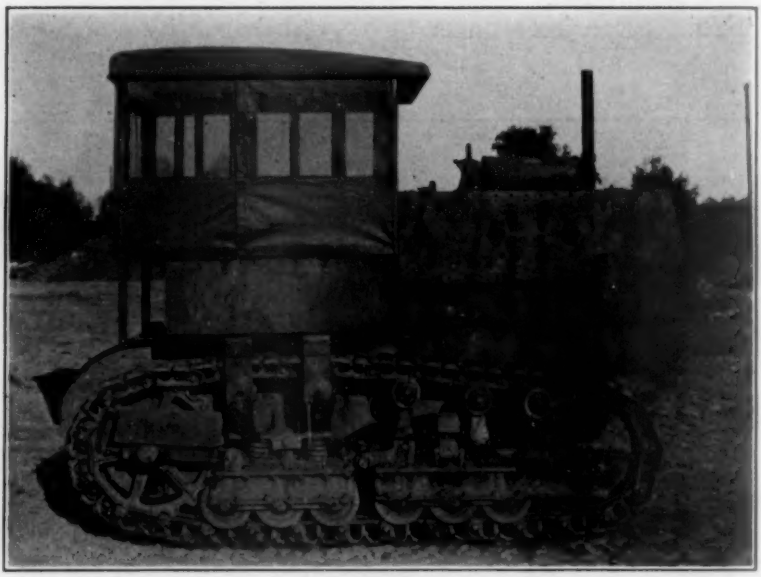
23. The French used for this purpose a 280 mm. howitzer firing a 600-pound projectile and a number of seacoast or Naval guns of calibres varying from 7-inches to 20-inches. These latter were mounted on Railway Carriages.

24. The British used howitzers of 9.2-inches in calibre and a collection of naval and seacoast guns up to 14-inches in calibre. The Germans, Austrians and Italians did about the same thing.

25. In considering the needs of our Army for Artillery of

this class, we had before us, first the French 280 mm. howitzer, which had too short a range, about 11,000 yards; second, the British 9.2-inch howitzer which had even shorter range than the French 280 mm.; and third, our own design of 9.5-inch howitzer which was then practically complete and which had a very satisfactory range. In view of the fact that the French had certain guns of 240 mm. calibre and a supply of ammunition

FIG. 18.



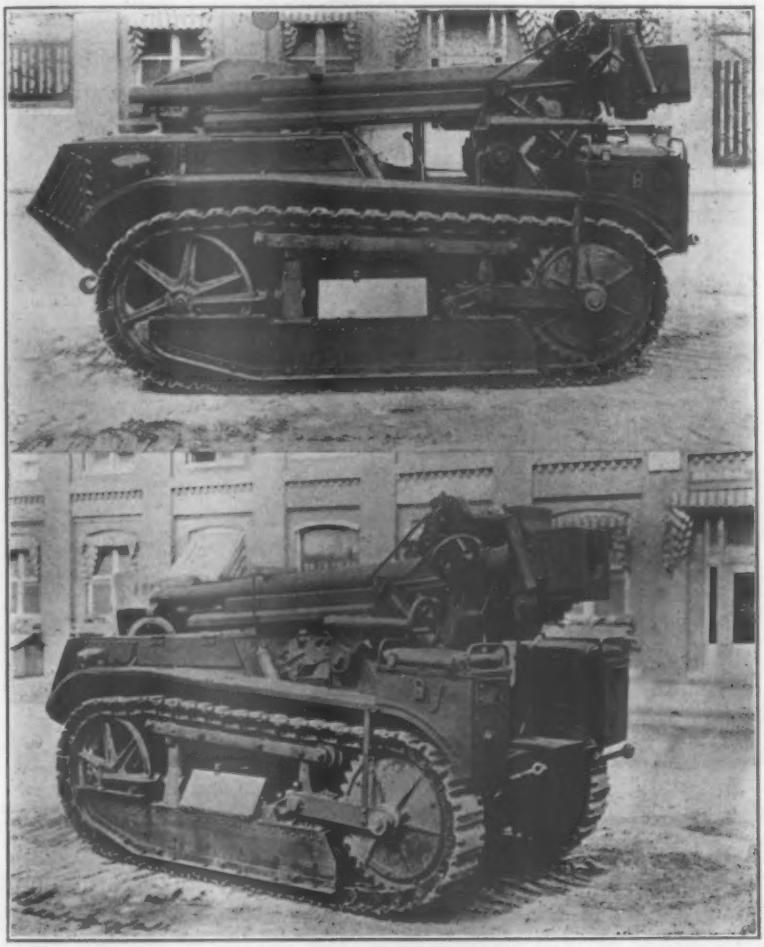
10-ton artillery tractor. Weight 21,500 pounds. Maximum speed 6 miles per hour. Draw bar pull low speed 8,000 pounds.

for them, we decided to change our 9.5-inch calibre to 240 mm. (9.45-inches) and to manufacture this type. In the meantime, we decided to procure from the British a number of 9.2-inch howitzers to fill the gap until our own guns could be delivered. As a matter of fact, due to the length of time required for the production of this class of material, only the 9.2-inch howitzers were used by our Army.

26. In addition to the above we withdrew from our Fortifications a number of 8-inch, 10-inch and 12-inch guns and mortars to be placed on railway mounts for the extreme long range firing

referred to before. The French were able to supply the requirements of our Army for this type of artillery until our own could be received.

FIG. 19.



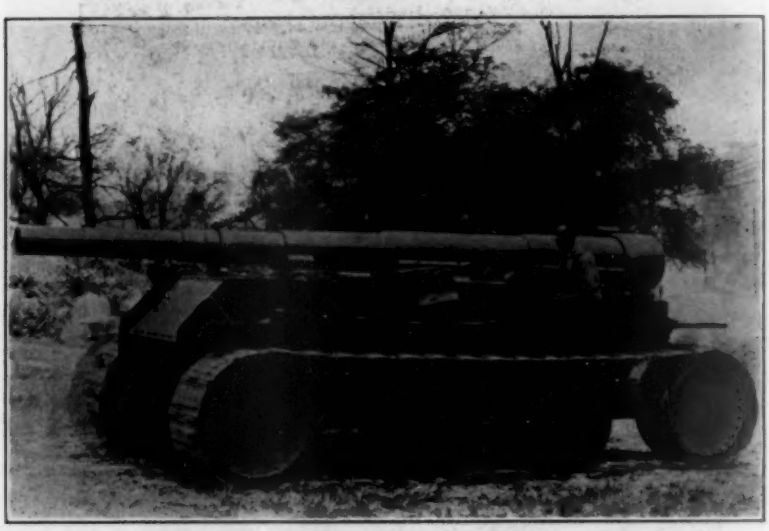
75-mm. gun on caterpillar mount. Capable of travelling at speeds of about 12 miles per hour. Maximum range 9,000 yards. Total weight 10,600 pounds.

27. Our Navy had a number of 14-inch guns which they were able to spare from their ship construction program and five of these guns were mounted by the Navy upon railway mounts

and were used for long range interdiction firing at various points of the front.

28. It will be of interest to note here that all nations engaged in the present war were compelled to make up their supply of this fourth and vitally important class of artillery almost entirely from guns in existence at the beginning of the War. There was neither time nor manufacturing facilities available for the manufacture of new and modern big guns. Consideration of these

FIG. 20.



155-mm. gun on Christie wheel caterpillar mount. This mount can travel as a wheeled vehicle or as a track laying caterpillar. Maximum speed as wheel vehicle 15 miles per hour. Maximum speed as caterpillar vehicle 10 miles per hour. Total weight 44,000 pounds.

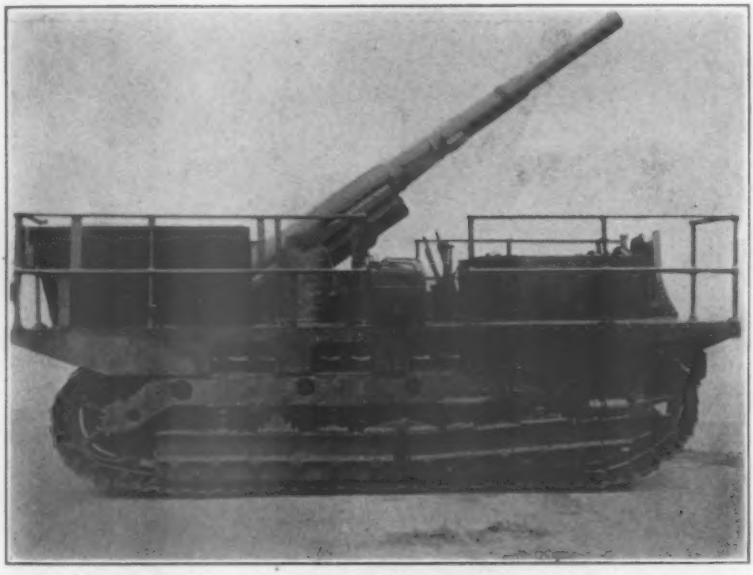
facts makes it evident that it behooves any nation to plan and prepare far into the future on this class of artillery.

29. I have described the types of artillery assigned normally to the principal tactical organizations. It must not be understood, however, that this assignment is unvarying, as such is not the case. In actual practice, the Divisional weapons form an integral part of the Division and are never separated from the Division. The Corps Artillery and the Army Artillery are more elastic and are often drawn from their normal assignments to fulfil special missions. The Army Reserve Artillery is

obviously special purpose artillery and is assigned to whatever Corps or armies are in special need of their services, depending upon the objectives to be obtained.

30. In speaking of types of artillery one must not forget that the object of artillery fire is to land a properly operating projectile on the target, and, therefore, we must remember that in all artillery design we must start with the projectile and work

FIG. 21.



155-mm. or 6" gun on caterpillar mount. Total weight including all equipment 61,000 pounds. Range with 96-pound projectile, 17,000 yards. Maximum road speed 5 miles per hour.

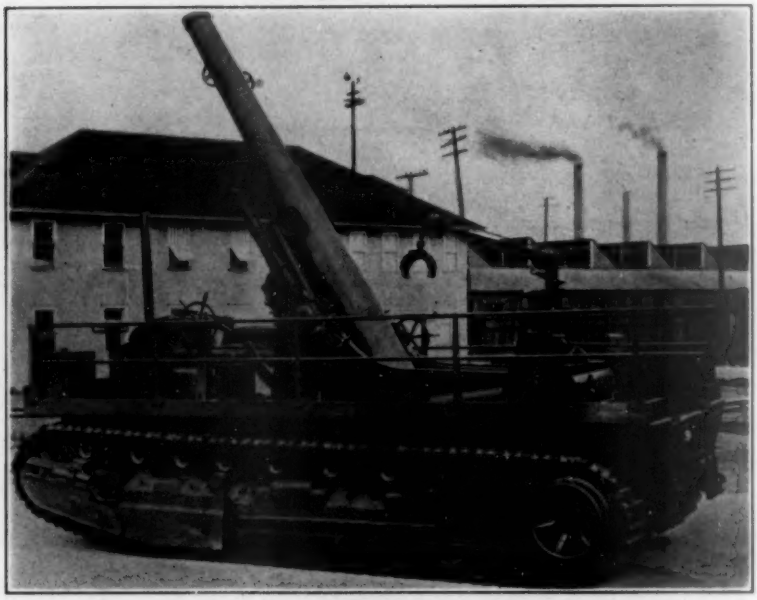
back to the gun and carriage. Any gun or any carriage is good if it will enable you to place projectiles upon the target. Guns and carriages are, therefore, a means to an end and the projectile is the prime factor in the equation. The projectile is of simple appearance on the outside and excites ordinarily but little curiosity as compared to the mechanism of the breech of a gun, or the recoil system of a carriage. The design and production of ammunition is however, of even greater importance than the design and production of guns and carriages.

31. For each standard type of gun such as the 155 mm., we

have about 16 different kinds of projectiles and I regret that my time is too short to enter into a discussion of some of the details on this phase of the subject.

32. Up to the present War we had considered that all Artillery except some special railway types must be transported by means of horses. The experience of previous wars had indicated that Divisional Artillery must be drawn by not more than six horses;

FIG. 22.



240-mm. howitzer on caterpillar mount. Maximum road speed 4 miles per hour. Total weight 109,000 pounds.

that Corps Artillery must be of a weight which could be drawn by eight horses and that heavy artillery must be divided up into a number of small loads each of which could be drawn by about eight horses.

33. Wheeled automobile traction is, of course, suitable on good roads, but is helpless on poor roads and across country. In 1912 and 1913 all of the major countries, with the United States in the lead, were experimenting with machines commonly known as caterpillar tractors for the purpose of hauling their

heavy artillery. The French and British purchased a large number of these machines in this country after their entrance into the War.

34. The French in spite of its limitations used a number of wheeled trucks for hauling their artillery and the British, Germans, Austrians and Italians did the same. The Divisional Artillery was, however, invariably drawn by horses. This was largely due to the fact that horses could be obtained and to the fact that tractors could not be obtained in sufficient quantities and in any case were not of entirely suitable design.

35. We were considerably in advance of other countries in our studies of this subject and we contemplated using horses for our Divisional Artillery with caterpillar tractors for all of the remainder, except our railway artillery. As a matter of fact, before the end of the war, it was decided to motorize one-half of all Divisional Artillery, due to the shortage of horses and the almost impossibility of securing forage for them.

36. We find then that at the time of the Armistice the United States was using horses for its Divisional Artillery, one-half of which were to be replaced as soon as possible with caterpillar tractors. All of our other Artillery was being motorized as rapidly as conditions permitted.

37. Three of the outstanding lessons of the War are; first, the tremendous use of ammunition, second, the development of special ammunition such as the gas shell, and third, the great increase in mobility and striking power which is given artillery by the advent of heavy railway artillery, motor traction and especially the caterpillar tractor.

38. The last is probably the greatest of all. The size of cannon and the supply of ammunition will cease to depend upon the muscle of the horses and will to a greater extent than ever before be independent of the roads. The offensive power of the artillery has been enormously increased and with the advent of tractors, tanks and self-propelled gun mounts able to negotiate streams five feet or more deep, it is not far fetched to imagine an army equipped with hundreds of armored machines moving freely over the country like ships at sea and engaging in almost hand-to-hand combat.

Permanent Preparation of the Antiscorbutic Vitamine.—The antiscorbutic food accessory or vitamine protects the body against scurvy. This disease attacks individuals who are on a restricted diet which does not contain such foods as *fresh* vegetables, fruits, milk, and meat. The antiscorbutic vitamine is abundant in the juice of fresh lemons. P. W. BASSETT-SMITH (*Lancet*, 1920, cxcviii, 1102–1105) has devised the following process for obtaining a preparation in which the vitamine retains its efficiency for a considerable period of time. Juice of fresh lemons is filtered through muslin, then is passed through filter paper under reduced pressure. The filtrate is evaporated *in vacuo* over sulphuric acid at a temperature of 13.5° to 15.5° C. The residue is a non-crystallizable syrup, which is worked into as stiff a paste as possible by incorporation with a dry mixture of anhydrous lactose 97 parts and gum tragacanth 3 parts. The paste is divided into portions, each of which contains the juice of one-half lemon and is equivalent to 24 c.c. of the juice—the dose for an adult. Each portion is rolled, faced with the dry mixture of lactose and gum, and pressed into a lozenge. Five days are required for the entire process of manufacture. The lozenges readily dissolve in water containing a small amount of sodium bicarbonate. They have been kept for three or more months at temperatures of 15°, 30° and 37° C. without loss of antiscorbutic power, and did not become mouldy. The temperature of 37° C. was least satisfactory; the lozenges became darker and softer; the lactose caramellized, and the vitamine was slightly affected. The antiscorbutic value of these lozenges was demonstrated by experiments on guinea-pigs which are extremely susceptible to scurvy.

J. S. H.

Ammonia-free Water.—According to GERALD C. BAKER (*Journal of Industrial and Engineering Chemistry*, 1920, xii, 798–799), ammonia-free water, which is required in the determination of ammonia, is readily prepared by permitting distilled water to flow slowly through a filter of "permutit," a synthetic hydrated silicate of sodium, and aluminium. Using distilled water containing 0.7 part of ammonia per million, 100 gallons of ammonia-free water were prepared with a filter containing 3 gallons of permutit. It was then necessary to regenerate the filter by treatment over night with 2 gallons of a 10 per cent. solution of common salt, followed by washing. While the water obtained by this mode of purification was ammonia-free, its mineral content was increased, and its nitrate, and albuminoid nitrogen were not removed. The raw water available was rather hard, and was not rendered ammonia-free by passing it through the permutit filter at as slow a rate as possible.

J. S. H.

THE USE OF ALTERNATING CURRENTS FOR SUBMARINE CABLE TRANSMISSION.*

BY

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ABSTRACT.

THIS paper contains the results of experiments performed by members of the Signal Corps Research Laboratory, Bureau of Standards, in an attempt to develop a method or methods of signal transmission over submarine cables which would permit of a more effective use of existing cable systems.

In the method proposed and developed, signals are transmitted by means of alternating currents simultaneously with the normal battery or direct-current operation of the cable. Currents of several different frequencies may be used, reserving a given frequency for each message, and by tuning or equivalent methods at the receiving end these messages may be separated, so that the simultaneous transmission of a number of messages is rendered possible.

Accurate determination of the fundamental physical properties of a particular cable for different frequencies has been accomplished, and the results are given herewith. From these physical properties accurate calculations for any length of cable can be made, so that the design of proper apparatus becomes purely a laboratory problem.

Actual trial of the proposed alternating-current method was made covering distances up to approximately 700 kilometres, with results which were in all cases completely satisfactory, indicating that the method is an entirely feasible one, and one which will render cables of this length, and undoubtedly of several times this length, much more useful.

I. THE GENERAL PROBLEM.

In March, 1919, in response to a request by the Chief Signal Officer for a consideration of the possibility of improving cable communication methods, the Signal Corps Research Laboratory

* Communicated by Maj. Gen. George Owen Squier, Chief Signal Officer, U. S. A.

commenced work with a view to ascertaining whether any practicable scheme could be devised which lay within its power to develop. After some deliberation it was decided that a possibility existed of using alternating currents as a means for transmitting signals over a submarine cable. The plan was not to use very low frequencies (5 to 10 cycles per second) and the ordinary type of receiver galvanometer, or equivalent apparatus, such as constitute the Squier Alternating Current Method ("On an Unbroken Alternating Current for Cable Telegraphy," George O. Squier, Proceedings of the Physical Society of London, August 15, 1915), but to use a frequency sufficiently high to produce an audible tone which could be received by means of an ordinary telephone receiver and further, so that several such alternating currents of different frequencies could be sent over the cable at the same time and separated at the receiving end by any one of the several well-known methods of tuning. Success in such a proposed scheme would make possible the multiplexing of submarine cables and, of course, provide for transmitting many more messages in a given time than can be done with present methods. Whatever success might be attained would be a net gain to the art, because the regular operation of the cable with direct current would proceed uninterruptedly.

As has long been known, the attenuation of alternating currents in or along submarine cables is very great on account of the resistance and capacity. This fact was considered at the time of formulating ideas in regard to possible methods, and calculations were made to determine the approximate magnitude of the attenuation for typical lengths and constructions of cables. The results of all calculations indicated that it would only be through the medium of powerful amplification at the receiving end that any success could be hoped for in the use of alternating currents of a frequency sufficiently high to permit of tuning, and over cables of such length as to make the method of military and commercial value. Had accurate information been available as to the values of the fundamental electrical properties of a cable when acted upon by an alternating electromotive force, rigorous calculation of the total attenuation could have been made, and upon this as a basis the amplifier design worked out purely as a laboratory problem.

As a matter of fact, little information was available concern-

ing the fundamental properties of a cable subjected to alternating currents of different frequencies. In common with all electrical systems the resistance of a cable should increase with increase in frequency, but the amount of this increase could be determined only by experiment. The magnetic field produced by the current within the cable sets up currents in the surrounding water and steel armor so that, in a general way, the increase in resistance with increase in frequency might well be expected to be similar in type to that observed in the case of a simple coil affected by the immediate proximity of another short-circuited coil. The direct-current, or zero-frequency, value of resistance is accurately known for any cable.

In regard to the self-inductance (coefficient of self-induction) of a cable no information could be found. The immediate presence of the steel armor and the uncertainty as to the geometrical distribution of the return current are factors which would make its calculation quite unreliable, if not worthless. Whatever its value might be, however, its variation with frequency should be of the same type as the variation of the apparent self-inductance of the simple coil system referred to in the preceding paragraph.

Because of the fact that the dielectric portion of the cable is well localized geometrically and of quite definite physical properties (being composed of either rubber or gutta percha) it would normally be expected that the apparent capacity and the dielectric loss coefficient would be dependent upon the frequency in the same way as in the case of a simple condenser, *i.e.*, a slight decrease in capacity and a practically constant power-factor angle.

The above general analysis is amply substantiated by the experimental results obtained from the measurements made on an actual cable. As the Signal Corps has available and operates the cable system between Seattle, Washington, and Sitka, Alaska, as well as a number of short cables in southeastern Alaska, it appeared that the most desirable procedure would be to utilize these various lengths of cable, as already laid, for the investigation of the problem in hand. The most important part of the experimental work lay in the determination of the four fundamental electrical properties previously mentioned, for such results are applicable generally. With such apparatus as could be developed in the short time available, however, excellent results

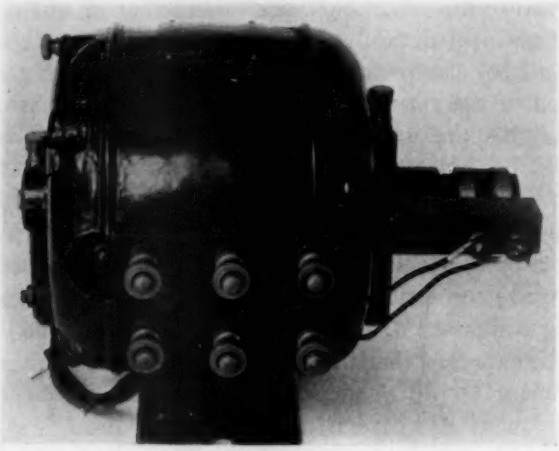
were obtained in the practical application of this method of signalling.

The description of apparatus used and the results obtained follows:

II. POWER SOURCES.

Whatever form the electrical signaling methods may take, safety to the cable insulation demands that the voltage impressed between cable conductor and sheath be limited to 70 volts. With an alternating emf. of sinusoidal wave form this means a limitation to 50 volts effective value. Throughout the range of

PLATE I.



frequencies from 0 to 1400 cycles per second preliminary approximate calculations indicated that a power of not over 40 watts would be required to impress this voltage on the cable. Preliminary calculations also showed that it would not be reasonable to expect much success from the use of frequencies higher than 1400 cycles per second.

For frequencies of from 7 to 40 cycles per second an inverted rotary converter was used as the power source. This machine was made by mounting a pair of slip rings on the shaft of a small direct-current motor and connecting them to electrically opposite points in the armature winding. The converter was driven and the voltage controlled by using the proper number of dry cells. Plate I shows the converter with its slip rings, and Plate II shows

the wave forms of voltage and current obtained when it is connected to a capacity load. The higher harmonics in the current wave I are considerably magnified when the machine feeds thus into a condenser, but since along a cable the higher frequencies are damped or attenuated much faster than the lower, these higher frequencies in the current are of little consequence. As matters turned out, this low-frequency generator was used very little.

For higher frequencies, an oscillating vacuum-tube generator capable of delivering 50 watts at any frequency above 20 cycles per second was developed. In this set standard Signal Corps

PLATE II.

50-watt vacuum tubes were used which, in order to gain flexibility of control, were arranged with one tube in an oscillating circuit and one tube in an amplifier circuit which was actuated by the first tube. From the last, or amplifier, tube the power was withdrawn by means of an iron-cored transformer.

In order to secure constancy in the frequency calibration an air-core inductance coil was used in the oscillating circuit. This coil, wound with No. 18 B. & S. double cotton-covered wire, contained approximately 3500 turns. Its ouside diameter was 28 cm. and its axial length 7.6 cm. Taps were brought out at intervals to provide for flexibility in the adjustment of the circuit conditions. When oscillating vigorously, the high voltage developed across the coil made it necessary to use a mica condenser capable of withstanding a working stress of 1000 volts, effective

alternating. A ten-microfarad condenser, adjustable in steps of 0.01 microfarad, gave excellent control of the frequency. Fig. 1 shows the essential features of the circuit arrangement.

The power output of the set was adjusted by means of the rheostats in the filament battery circuits. Separate storage bat-

FIG. 1.

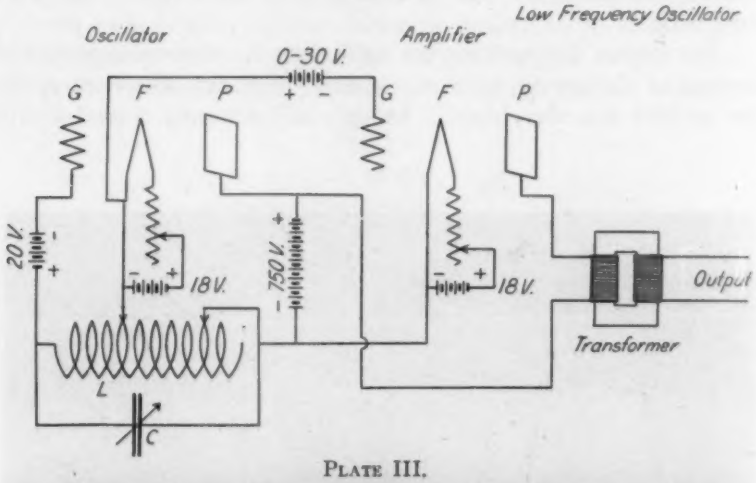


PLATE III.

teries were used for lighting the filaments, while a single battery of approximately 600 dry cells was used in the plate circuits of both tubes. For all ordinary purposes it was found possible to calculate the frequency from the known values of capacity and inductance in the oscillating circuit, using the usual formula. This is true for the kind of circuit used when the condenser capacity is large in comparison with the capacity of the coil. The

following tables give the principal electrical properties of the oscillating circuit, and show how a complete range of frequencies can be covered by the use of only two of the taps in the coil:

TABLE I.

Inductance of Oscillator Coil.

Taps Counted from Inside of Coil Outwards.

Taps	Turns	Inductance henrys	
0–1	324	0.0142	Outside diameter, 28 cm.
0–2	648	0.0587	
0–3	972	0.138	Axial length, 7.6 cm.
0–4	1296	0.254	
0–5	1620	0.408	Winding of No. 18 B. & S. gage, double cotton insulated wire.
0–6	1944	0.605	
0–7	2268	0.846	
0–8	2592	1.125	
0–9	2916	1.448	
0–10	3240	1.818	
0–11	3456	2.094	

TABLE II.

Frequency Calibration of Oscillator.

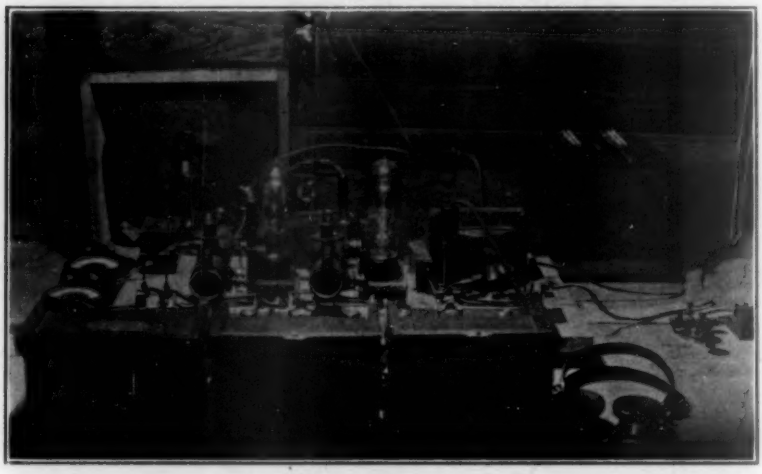
Frequency in Cycles Per Second when Condenser is Connected Across Taps 0–11 and Across Taps 0–3.

Capacity mf.	Taps 0–11 frequency	Taps 0–3 frequency
30.2	20.00	.....
11.1	33.01	.....
10.0	34.78	135.5
9.0	36.66	142.8
8.0	38.88	151.5
7.0	41.57	161.9
6.0	44.90	174.9
5.0	49.19	191.6
4.0	54.99	214.2
3.0	63.50	247.4
2.0	77.77	303.0
1.5	89.80	349.8
1.0	109.9	428.4
0.9	115.9	451.6
0.8	122.0	479.0
0.7	131.5	512.1
0.6	142.0	553.1
0.5	155.5	605.9
0.4	174.0	677.4
0.3	200.8	782.2
0.2	245.9	958.0
0.1	347.8	1355.0

Plate III shows the wave forms of current and voltage produced by the oscillator when operating at a frequency of 200 cycles per second and when feeding into a capacity load.

Plate IV shows the arrangement of the panel containing the various elements of the oscillator. The coil and condenser are included in the photograph. The oscillator here described was used for the major portion of all experimental work. In certain

PLATE IV.



cases, where only a small amount of power was required, as in the calibration of apparatus, a similar but lower-powered oscillator was used.

MEASUREMENT OF THE ELECTRICAL PROPERTIES OF THE SEATTLE-SITKA CABLE.

Upon arrival at Seattle, Washington, in June, 1919, steps were taken to proceed immediately with determination of the fundamental electrical properties of the cable and of their dependence upon the frequency. Several methods are available for making such determinations, but the one selected as being most suitable for the case in hand was that in which the apparent impedances of a moderate length of cable are measured by means of an impedance bridge, both when the remote end is short circuited and when it is open circuited.

A short length (14 kilometres) of cable of the same type as the main Seattle-Sitka cable was available continuously for this experimental work. It extended from the foot of University Street, Seattle, to the cable hut at Fort Lawton, and at both ends the cable passed directly into salt water, making conditions practically uniform and ideal throughout its length. Excellent ground connections at both ends were provided by soldering leads to the several strands of the cable sheath. The conclusion that the physical arrangements were such as to eliminate errors arising from end effects was amply borne out by the results of certain check measurements to be described later.

The technical specifications for the cable upon which the measurements were made are given in Table III. The cable in question is made up of a stranded copper core, rubber insulation bound with tape, a layer of jute, and then the stranded steel armor with its serving of impregnated jute.

TABLE III.

Alaskan Cable Specifications.

Data taken from Signal Corps Manual No. 3, Chap. 11, p. 73.

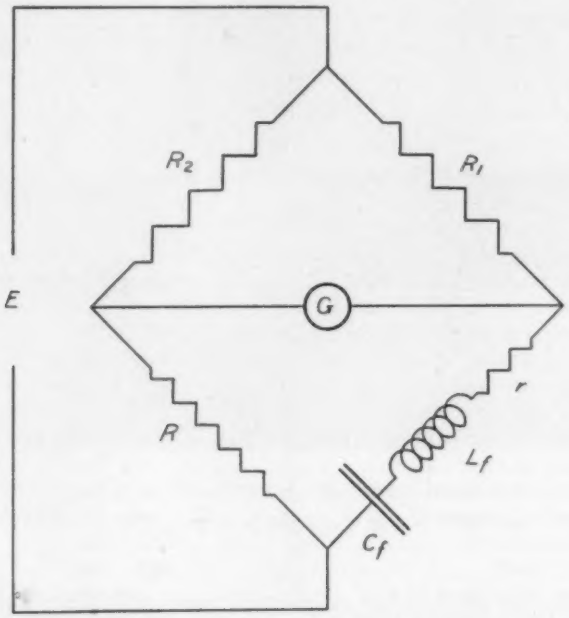
Type, 1903, Deep sea

Outside diameter of cable	2.06	cm.
Weight of whole cable in air	881	kg. per km.
Weight of whole cable in water	569	kg. per km.
Weight of armor wire	577	kg. per km.
Weight of jute and compound	217	kg. per km.
Weight of tape	16.1	kg. per km.
Weight of rubber insulation	43.1	kg. per km.
Weight of copper	32.4	kg. per km.
Breaking stress	6610	kg.
Elastic limit	4990	kg.
Copper resistance at 15.5° C.	4.59	ohms per km.
Dielectric resistance at 15.5° C.	2280	megohms for 1 km.
Electrostatic capacity	0.266	mf. per km.

Before doing any experimental work all apparatus was carefully calibrated. Only two separate standards, namely, a capacity standard and a resistance standard, were required to establish the accurate calibration of all condensers, resistances, and inductances used. For the former, the Bureau of Standards certification of section 0.1 A (0.1000 mf.) of Leeds and Northrup mica condenser No. 47839 was accepted. In order to avoid cumulative errors in the fourth significant figure another cipher was added to the above

value in making up the calibration data. For a resistance standard the Leeds and Northrup precision Wheatstone Bridge No. 3445, installed in the Seattle Cable Office, was used. Before accepting this bridge as standard the sections therein were carefully compared and also checked against other high-grade resistance boxes. In the few cases where the indications of electrical meters are quoted, the meters had been calibrated against auxiliary standards calibrated by the Department of Physics of the University of Washington.

FIG. 2.



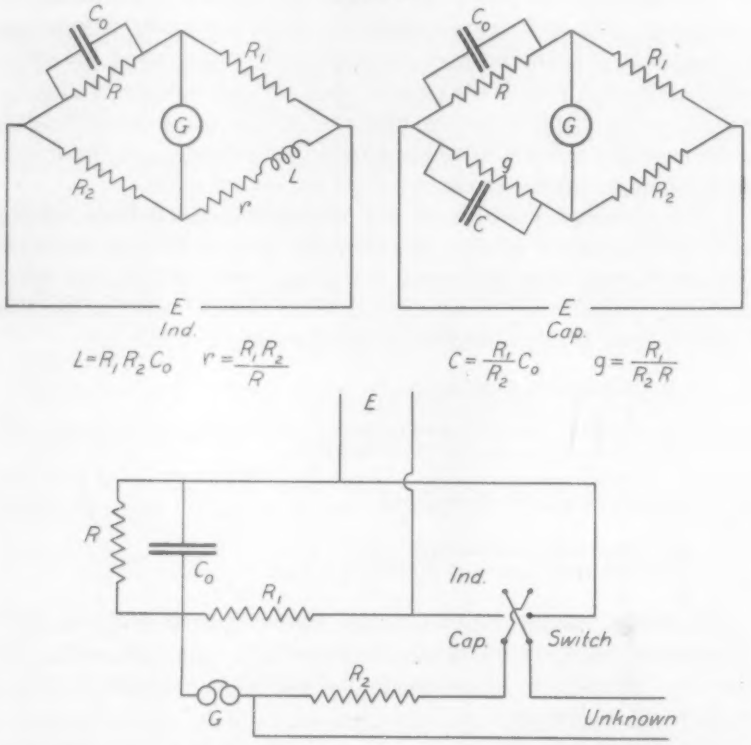
Frequencies were determined in terms of capacity and inductance by means of the resonance frequency bridge shown in Fig. 2. In this bridge, the conditions for balance are

$$\left.\begin{aligned} R_1 R &= R_2 r \\ \omega^2 &= \frac{1}{L_f C_f} \end{aligned}\right\} \qquad (1)$$

in which $\omega = 2\pi f$ and f = frequency in cycles per second. The L_f or C_f adjustment for balance can be made with nicety, so that the frequency determinations are of the same degree of accuracy

as the values taken for the two standards of capacity and resistance. In some of the field work calibrated tuning forks were used to give fixed frequencies to which the oscillator frequencies were adjusted. Elimination of beats between the sound of the fork and the sound produced by the alternating current in a telephone receiver served, in this method, to determine the frequencies to within one cycle per second, or closer.

FIG. 3.



The type of alternating-current impedance bridge used in making the measurements is shown in Fig. 3, and is more fully described in Sections 103 and 104 of Pernot, "Electrical Phenomena in Parallel Conductors," vol. i. For an inductive impedance with the "IND." arrangement of the bridge, the apparent resistance r, and the apparent self-inductance L, are obtained from the formulæ given in the figure. With the "CAP." bridge

arrangement, the apparent conductance g, and the apparent capacity C, are obtained from the appropriate formulæ. Therefore, impedances Z, or admittances Y are given by

$$\left.\begin{aligned} &\text{"IND." bridge, } r = \frac{R_1R_2}{R},\ L = R_1R_2C_0,\ Z = r + j\omega L,\ Y = \frac{1}{Z} \\ &\text{"CAP." bridge, } g = \frac{R_1}{R\,R_2},\ C = \frac{R_1}{R_2}C_0,\ Y = g + j\omega C,\ Z = \frac{1}{Y} \end{aligned}\right\} \quad (2)$$

For frequencies above 100 cycles per second a telephone receiver was used as a current detector, while for lower frequencies a vibration galvanometer was employed. Insulating transformers were used in both the power input and galvanometer circuits. All of the elements entering into the bridge were carefully calibrated against the previously mentioned standards, and the results in all cases are given in terms of the corrected values.

The essential features of the mathematical analysis leading to a determination of the fundamental line properties from the two impedance measurements, previously referred to, are given here for convenience in reference. The fundamental properties, whose values at the different frequencies are desired, are:

$$\left.\begin{aligned} r &= \text{resistance per unit length} \\ L &= \text{self inductance per unit length} \\ g &= \text{dielectric-loss coefficient (leakance) per unit length} \\ C &= \text{electrostatic capacity per unit length} \end{aligned}\right\} \quad (3)$$

or, as more compactly expressed,

$$\left.\begin{aligned} Z &= \text{impedance per unit length} = r + j\omega L \\ Y &= \text{admittance per unit length} = g + j\omega C \end{aligned}\right\} \quad (4)$$

With the remote end of the line short-circuited, and then with the remote end open-circuited, the respective impedances are (see Pernot, "Electrical Phenomena in Parallel Conductors," vol. i, sections 95 and 100):

$$\left.\begin{aligned} Z' &= U \tanh Vl = \text{apparent short-circuited impedance} \\ Z'' &= U \coth Vl = \text{apparent open-circuited impedance} \end{aligned}\right\} \quad (5)$$

in which

$$\left.\begin{aligned} U &= \sqrt{\frac{Z}{Y}} = \text{infinite-line impedance} \\ V &= \sqrt{Z\,Y} = \text{propagation constant} \\ l &= \text{length of line or cable.} \end{aligned}\right\} \quad (6)$$

The problem is to evaluate Z and Y in terms of Z'' and Z', since the two last impedances are those which are determined by measurement. The auxiliary quantities U and V are also desired.

By multiplication of the two equations in (5)

$$U = \sqrt{Z' Z''} \tag{7}$$

Then, from equations (5),

$$V = \frac{1}{l} \tanh^{-1} \frac{Z'}{U} = \frac{1}{l} \coth^{-1} \frac{Z''}{U} \tag{8}$$

The two quantities U and V, which directly determine the behavior of the system in the transmission of alternating currents of the particular frequency in question, are thus immediately determined. The fundamental electrical properties are derivable from them by the aid of equations (6);

$$\left.\begin{aligned} Z &= r + j\omega L = UV \\ Y &= g + j\omega C = \frac{V}{U} \end{aligned}\right\} \tag{9}$$

This completes the solution, for the imaginary portions in equations (9) when divided by ω give respectively the self-inductance L and the capacity C.

In the process of computing, the inverse hyperbolic tangent of the complex quantity $\frac{Z'}{U}$, as required by (8), is most easily obtained by logarithmation after expressing the tangent in exponential form. The result is

$$V = \frac{1}{2l} \ln \frac{U - Z'}{U + Z'} \tag{10}$$

In order to obtain a check on the experimental work, similar measurements were made from both ends of the 14-kilometre length available. As a further check, measurements at different frequencies were made of the apparent impedance at one end when the remote end was closed through a known impedance. Having found the fundamental line properties at these same frequencies, the apparent impedance can be calculated in terms of them and the known impedance at the remote end. The formula for this apparent impedance is

$$Z_a = \frac{Z_0 \cosh Vl + U \sinh Vl}{\cosh Vl + \frac{Z_0}{U} \sinh Vl} \tag{11}$$

where Z_o is the known impedance at the remote end and Z_a is the apparent impedance.

A comparison of the calculated and observed values of Z_a furnishes a basis for estimating the accuracy of the fundamental determinations.

Tables IV, V, and VI give the corrected values of the quantities observed in the bridge measurements. They lead to values of r and L or of g and C through the formulæ pertaining to the type of bridge used, and the results must, in some cases, be corrected by the conductance of a known resistance shunting the line terminals connected to the bridge. In Table IV the frequencies f were determined directly by adjusting the oscillator frequencies to those of calibrated tuning forks. The other values tabulated are those of the quantities shown in the bridge diagram, Fig. 3. Observations 1, 2, and 3 are not given because they were preliminary, trial settings, not made with much care. In Tables V and VI, L_f and C_f are the corrected values of inductance and

TABLE IV.

Corrected Data from Impedance Measurements Made at Seattle End.

Length of cable, 14.294 km.

No.	Bridge type	Shunt resistance	f cyc./sec.	R_1 ohms.	R_2 ohms.	R ohms.	C_0 farads
		Cable short circuited at remote end.					
4	IND	Inf.	400	99.96	99.92	106.54	0.53558×10^{-6}
5	IND	Inf.	384	99.96	99.92	107.85	0.56993×10^{-6}
6	IND	Inf.	320	99.96	99.92	113.81	0.68624×10^{-6}
7	IND	Inf.	200	99.96	99.92	123.87	0.93999×10^{-6}
8	IND	Inf.	512	99.96	99.92	98.28	0.32313×10^{-6}
9	CAP	Inf.	824	1000.4	999.6	117.33	0.21960×10^{-6}
10	CAP	Inf.	652?	1000.4	99.92	1111.6	0.00000×10^{-6}
		Cable open circuited at remote end.					
11	CAP	200.14	400	1000.4	99.92	1187.0	0.37592×10^{-6}
12	CAP	200.14	200	1000.4	99.92	1700.0	0.38829×10^{-6}
13	CAP	200.14	320	1000.4	99.92	1391.8	0.38143×10^{-6}
14	CAP	200.14	512	1000.4	99.92	923.99	0.36076×10^{-6}
15	CAP	200.14	824	1000.4	99.92	493.44	0.24626×10^{-6}
16	CAP	200.14	640?	1000.4	99.92	664.00	0.32112×10^{-6}
17	CAP	200.14	634?	1000.4	99.92	703.87	0.33055×10^{-6}
18	CAP	200.14	824	1000.4	99.92	492.74	0.24580×10^{-6}
19	CAP	200.14	435	1000.4	99.92	1100.1	0.37224×10^{-6}
20	CAP	200.14	256	1000.4	99.92	1558.9	0.38505×10^{-6}

In observations 10, 16, and 17 the frequencies were determined from the capacity and inductance settings of the oscillator, so that they may be in error by a number of cycles. These observations were not used in the determination of the line properties. Observation 10 was taken particularly in order to observe the change in impedance of the short-circuited cable from an inductive to a condensive nature. At this observation the reactance was zero.

capacity involved in determining the frequency by means of the resonance bridge shown in Fig. 2. In a few cases the frequencies, as determined by direct comparison with tuning forks, are given in place of L_f and C_f.

TABLE V.

Corrected Data from Impedance Measurements Made at Fort Lawton End.

Length of cable, 14.294 km.

No.	Bridge type	Shunt resist.	Lf henrys	Cf farads	R_1 ohms	R_2 ohms	R ohms	C_0 farads
		Cable short circuited at remote end.						
21	IND	Inf.	0.31320	0.50387×10^{-6}	99.96	99.92	104.24	0.49839×10^{-6}
22	IND	Inf.	0.14140	0.50387×10^{-6}	99.96	99.92	91.87	0.09316×10^{-6}
26	IND	Inf.	f = 199.3		99.96	99.92	122.98	0.92814×10^{-6}
28	IND	Inf.	0.39895	0.95447×10^{-6}	99.96	99.92	118.21	0.78543×10^{-6}
23	CAP	Inf.	0.42433	0.10000×10^{-6}	99.96	99.92	115.11	0.21731×10^{-6}
24	CAP	Inf.	0.24900	0.10000×10^{-6}	499.90	99.92	588.54	0.10050×10^{-6}
25	CAP	Inf.	0.30151	0.050051×10^{-6}	99.96	99.92	107.04	0.72090×10^{-6}
		Cable open circuited at remote end.						
29	CAP	Inf.	0.39895	0.95447×10^{-6}	1000.4	99.92	7148.2	0.38458×10^{-6}
30a	CAP	500.5	f = 199.3		1000.4	99.92	3459.2	0.38733×10^{-6}
30b	CAP	500.5	f = 199.3		1000.4	99.92	3471.3	0.38634×10^{-6}
31	CAP	Inf.	0.31320	0.50387×10^{-6}	1000.4	99.92	2975.0	0.37648×10^{-6}
32	CAP	Inf.	0.14140	0.50387×10^{-6}	1000.4	99.92	1270.7	0.34647×10^{-6}
33	CAP	Inf.	0.42433	0.10000×10^{-6}	1000.4	99.92	746.88	0.28499×10^{-6}
34	CAP	Inf.	0.24900	0.10000×10^{-6}	1000.4	99.92	508.00	0.16155×10^{-6}
35a	CAP	Inf.	0.30151	0.050051×10^{-6}	1000.4	99.92	478.14	0.04416×10^{-6}
35b	CAP	Inf.	0.30151	0.050051×10^{-6}	99.96	99.92	47.86	0.44327×10^{-6}

TABLE VI.

Corrected Data from Impedance Measurements Made at Fort Lawton End. Check Test with Known Value of Z_0.

Length of cable, 14.294 km.

Remote End Closed Through 100.01 Ohms Resistance ($=Z_0$).

No.	Bridge type	Shunt resist.	Lf henrys	Cf farads	R_1 ohms	R_2 ohms	R ohms	C_0 farads
36	CAP	Inf.	0.39895	0.95447×10^{-6}	499.90	99.92	777.90	0.36732×10^{-6}
37	CAP	Inf.	f = 199.3		499.90	99.92	806.91	0.36931×10^{-6}
38	CAP	Inf.	0.31320	0.50387×10^{-6}	499.90	99.92	691.37	0.35527×10^{-6}
39	CAP	Inf.	0.14140	0.50387×10^{-6}	499.90	99.92	567.48	0.32793×10^{-6}
40	CAP	Inf.	0.42433	0.10000×10^{-6}	499.90	99.92	470.87	0.29272×10^{-6}
41	CAP	Inf.	0.24900	0.10000×10^{-6}	499.90	99.92	379.88	0.23276×10^{-6}
42	CAP	Inf.	0.30151	0.050051×10^{-6}	499.90	99.92	320.52	0.15494×10^{-6}

After reduction by equations (1) and (2) the foregoing data yield the apparent impedance (or admittance) components given in Tables VII and VIII. Only four significant figures are tabulated, although all computations, up to and including the final results, were carried out to five.

TABLE VII.

Components of Apparent Impedances from Measurements at Seattle End.

Cable short circuited				Cable open circuited		
f	No.	r' ohms	L' henrys	No.	g'' mhos	C'' farads
200	7	80.63	0.009389	12	0.0008929	3.888×10^{-6}
256	..	.....	.....	20	0.0014259	3.855×10^{-6}
320	6	87.76	0.006854	13	0.002197	3.819×10^{-6}
384	5	92.61	0.005692	..	.....	.....
400	4	93.75	0.005349	11	0.003438	3.764×10^{-6}
435	..	.....	.....	19	0.004104	3.727×10^{-6}
512	8	101.63	0.003228	14	0.005840	3.612×10^{-6}
634	..	.....	.....	17	0.009228	3.310×10^{-6}
640	..	.....	.....	16	0.010082	3.215×10^{-6}
		g' mhos	C' farads			
652	10	0.009007	0.00000×10^{-6}	.....	.....	.....
824	9	0.008530	0.2198×10^{-6}	15 and 18	0.015308	2.463×10^{-6}

Observations 15 and 18 agree so well that the average of their values is tabulated above. The components r', L' or g', C' and g'', C'', go to make up the impedances Z' and Z'', respectively.

TABLE VIII.

Components of Apparent Impedances from Measurements at Fort Lawton End.

Cable short circuited				Cable open circuited		
f	No.	r' ohms	L' henrys	No.	g'' mhos	C'' farads
199.3	26	81.22	0.009270	30	0.0008899	3.873×10^{-6}
257.9	28	84.49	0.007845	29	0.0014006	3.850×10^{-6}
400.6	21	95.82	0.004978	31	0.003365	3.769×10^{-6}
596.3	22	108.72	0.0009305	32	0.007879	3.469×10^{-6}
		g' mhos	C' farads			
772.6	23	0.008691	0.2174×10^{-6}	33	0.013405	2.853×10^{-6}
1008.6	24	0.008501	0.5028×10^{-6}	34	0.01971	1.617×10^{-6}
1295.6	25	0.009346	0.7212×10^{-6}	35	0.02092	0.4428×10^{-6}

Observation 30 in the above table is the average of the values obtained from observations 30*a* and 30*b* in Table V. Similarly with observation 35.

From the components of Z' and Z'' given in the two foregoing tables, the fundamental line properties per unit of length are to be calculated in accordance with equations (7), (8), (9), and (10). Although these equations appear simple, the fact that the quantities entering therein are complex makes the carrying out of the numerical work rather laborious. A sample computation of the kind required is to be found in Section 106, "Electrical Phenomena in Parallel Conductors."

Table IX gives the final results of the computations based upon the data in Tables VII and VIII. In addition to the four fundamental electrical properties, their combinations into impedances and admittances per unit of length are given also.

TABLE IX.

Fundamental Cable Properties per Kilometre.

f	r ohms/km.	L henrys/km.	$10^6 g$ mhos/km.	$10^6 C$ farads/km.	Z ohms	$10^6 Y$ mhos
	Measurements from Seattle End.					
0	4.660	.....	0.0030	.....	$4.660/0°$	$0.0030/0°$
200	5.388	0.001215	17.02	0.2712	$5.600/15.82°$	$341.3/87.14°$
320	5.557	0.001100	29.80	0.2670	$5.981/21.71°$	$537.7/86.82°$
400	5.686	0.001057	36.02	0.2650	$6.276/25.04°$	$666.9/86.90°$
512	5.813	0.001006	50.43	0.2628	$6.653/29.10°$	$847.0/86.59°$
824	6.147	0.000928	107.31	0.2575	$7.801/38.00°$	$1337.5/85.40°$
	Measurements from Fort Lawton End.					
0	4.660	.....	0.0030	.....	$4.660/0°$	$0.0030/0°$
199.3	5.432	0.001214	17.09	0.2704	$5.641/15.64°$	$339.1/87.11°$
257.9	5.513	0.001141	20.23	0.2683	$5.815/18.54°$	$435.2/87.34°$
400.6	5.810	0.0010585	27.24	0.2643	$6.392/24.64°$	$665.9/87.66°$
596.3	6.023	0.0009588	38.46	0.2613	$7.013/30.81°$	$979.8/87.75°$
772.6	6.191	0.0008850	52.74	0.2617	$7.535/34.76°$	$1272/87.62°$
1008.6	6.404	0.0008314	73.88	0.2636	$8.293/39.44°$	$1672/87.47°$
1295.6	6.551	0.0007947	129.6	0.2645	$9.206/44.64°$	$2157/86.56°$

The complex values of Z and Y are given in the above table in the form of a scalar value and angle.

The values of r, L, g, C, and θy as given in the above table are shown plotted as functions of the frequency in Figs. 4, 5, 6, 7, and 8. The dotted lines connect the observations made at the Seattle end and the full lines connect the observations made at the Fort Lawton end. In estimating the consistency of the results from the appearance of the curves, due regard must be paid to the greatly magnified scales used in some cases.

The quantities which enter more directly into the equations determining the manner of transmission of alternating currents than do the fundamental electrical properties themselves, are:

$$u = \sqrt{\frac{z}{y}} = \text{infinite-line impedance, ohms;}$$

$$\theta_u = \frac{1}{2}(\theta_z - \theta_y) = \text{angle of infinite-line impedance;}$$

$$U = u \angle \theta_u$$

α = real portion of V = attenuation constant; numeric per km.

β = imaginary portion of V = wave-length constant; radians per km.

$S = \frac{\omega}{\beta}$ = velocity of propagation; km. per sec.

$\lambda = \frac{2\pi}{\beta}$ = wave length; km.

The values of the above quantities as determined from the measurements and in the units specified above are given in Table X.

TABLE X.

Transmission Constants for Alternating Currents.

f	α km. $^{-1}$	β km. $^{-1}$	u ohms	Θu	S km./sec.	λ km.
		Measurements from Seattle End.				
0	0.00011	0.00000	39000	00000	.....	.....
200	0.02723	0.03421	128.10	−35.66°	36740	183.7
320	0.03312	0.04604	105.47	−32.55°	43680	136.5
400	0.03620	0.05362	97.01	−30.93°	46870	117.2
512	0.03995	0.06356	88.63	−28.74°	50620	98.86
824	0.04843	0.08994	76.37	−23.70°	57560	69.86
		Measurements from Fort Lawton End.				
0	0.00011	0.00000	39000	00000	.....	.....
199.3	0.02730	0.03417	129.0	−35.73°	36650	183.9
257.9	0.03032	0.04015	115.6	−34.40°	40360	156.5
400.6	0.03635	0.05418	97.97	−31.51°	46460	115.96
596.3	0.04234	0.07126	84.60	−28.47°	52580	88.17
772.6	0.04717	0.08577	76.98	−26.43°	56600	73.25
1008.6	0.05263	0.10535	70.42	−24.01°	60150	59.64
1295.6	0.05822	0.12834	65.33	−20.96°	63430	48.96

TABLE XI.

Infinite-line Impedance of Sitka-Seattle Cable.

Measured at Sitka.

f cyc.	Conductance, mhos	Susceptance, mhos	U ohms and angle
22.18	0.002234	0.001873	343.0/39.97°
33.59	0.002678	0.002235	286.6/39.85°
39.80	0.002893	0.002410	265.6/39.79°
46.58	0.003108	0.002585	247.4/39.75°
56.41	0.003394	0.002816	226.8/39.69°
81.44	0.004031	0.003306	191.8/39.36°
95.47	0.004359	0.003532	178.2/39.02°
131.09	0.005152	0.003994	153.4/37.78°
161.78	0.005742	0.004262	139.8/36.59°
203.1	0.006450	0.004597	126.2/35.48°
245.8	0.007140	0.004892	115.5/34.42°
296.0	0.007694	0.005025	108.8/33.15°
384.3	0.008696	0.005315	98.12/31.43°
476.5	0.009593	0.005492	90.47/29.78°
613.8	0.01079	0.005491	82.60/26.97°
739.2	0.01164	0.005382	77.98/24.82°
859.0	0.01228	0.005195	74.99/22.93°
1039.0	0.01296	0.004935	72.09/20.84°
1184.0	0.01334	0.004794	70.53/19.76°

In the above table the conductance and susceptance as tabulated are the two components of the reciprocal of U. The angle of U is to be counted as negative.

The attenuation constant α is shown as a function of the frequency in Fig. 9. The data obtained from the two sets of measurements are in such close agreement that a single curve suffices to represent all of the points.

FIG. 4.

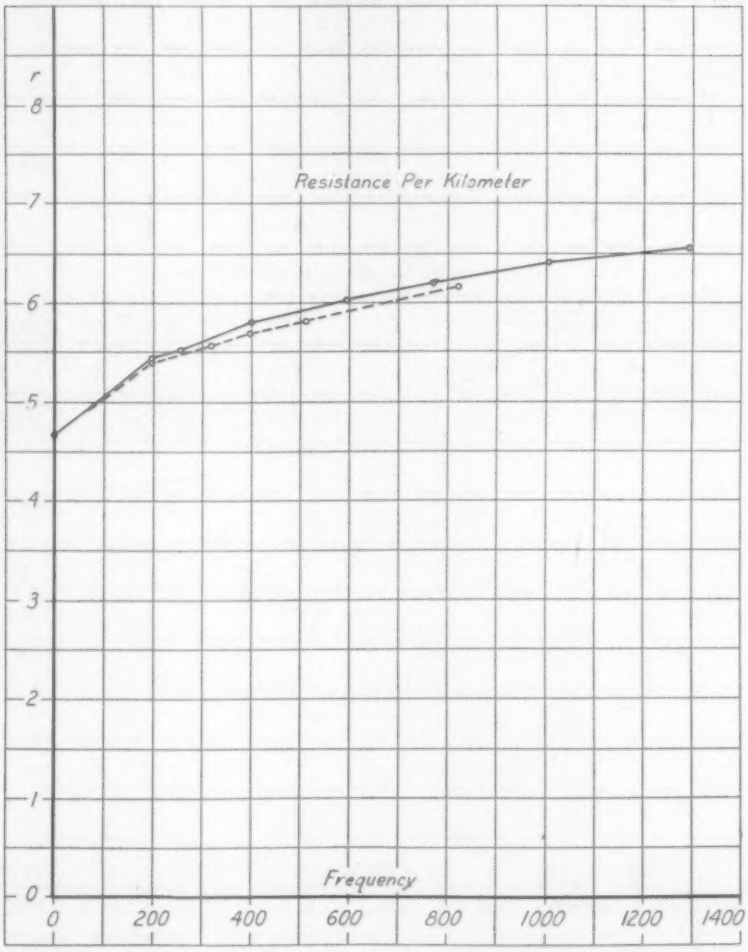
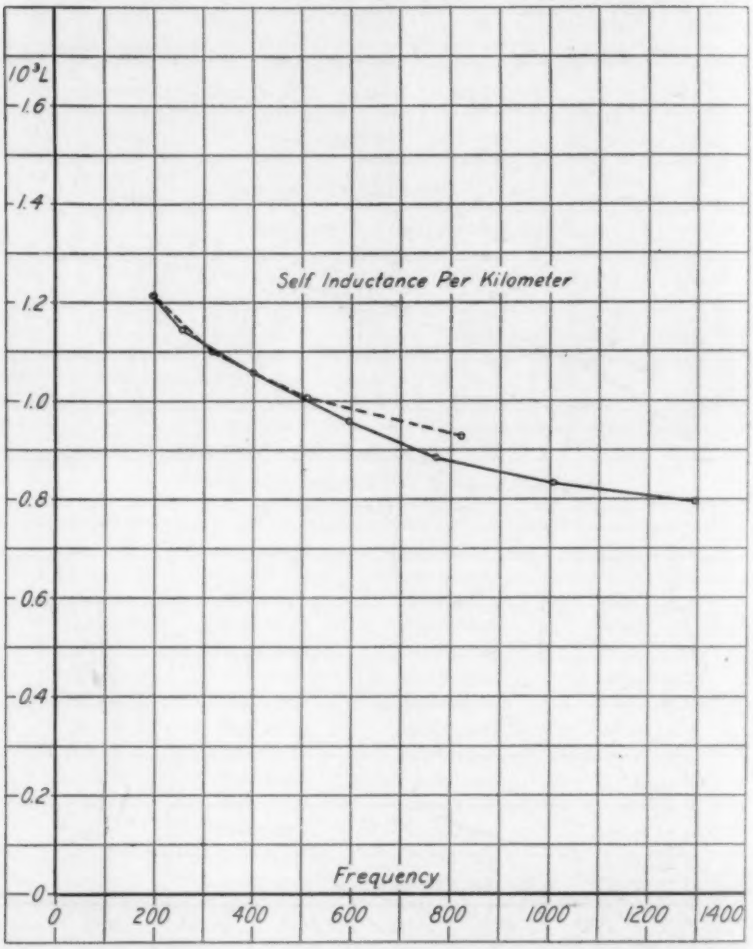


Fig. 10 shows the scalar value of the infinite-line impedance u. In addition to the values given in Table X it contains the values determined by measurements made at Sitka, Alaska, on the long cable (approximately 1700 kilometres) between there and Seattle.

As far as the tabulated frequencies are concerned, this constitutes an infinite length, or at any rate, a length sufficient to prevent conditions at the remote end from affecting the measured impedances

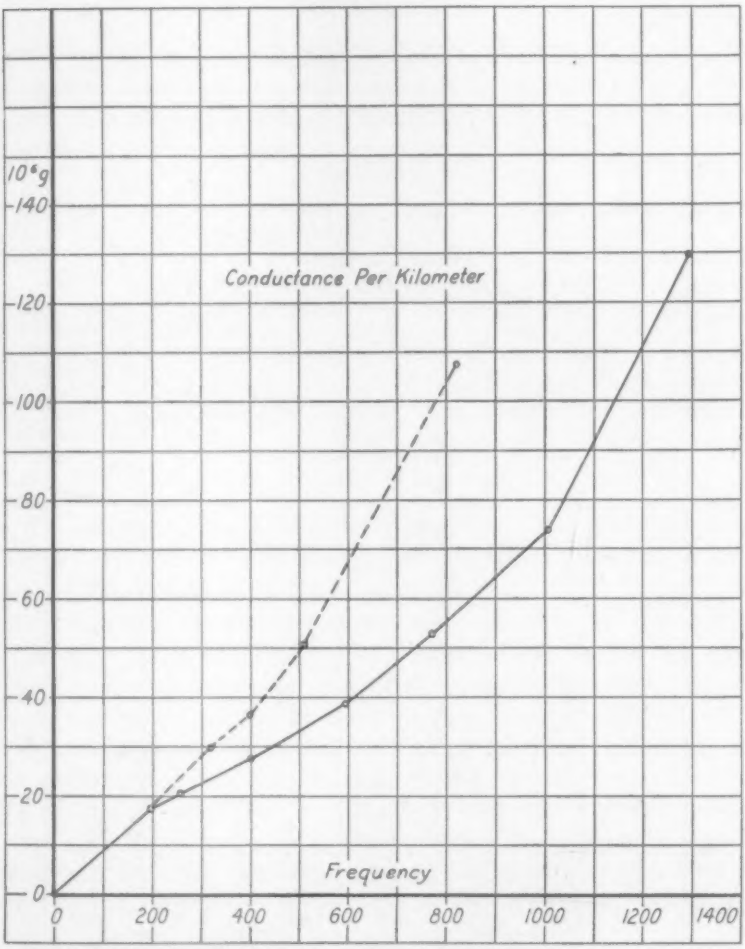
FIG. 5.



at the input end. The data obtained in these measurements at Sitka are given in Table XI. Because of the great length, a single determination with the impedance bridge gave the desired result immediately. Both in the case of u and of θ_u the agreement

between the values determined by the two impedance measurements on the short Seattle-Fort Lawton cable and by the single impedance measurements on the long Sitka-Seattle cable is excel-

FIG. 6.

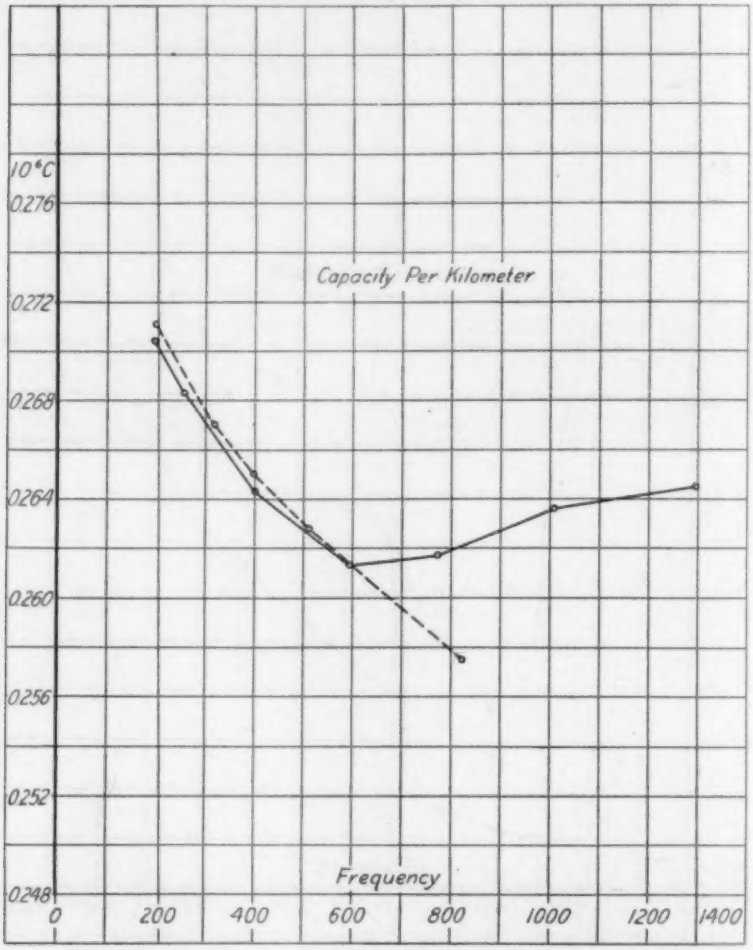


lent, indicating that the measurements are reliable and that the cables are similar electrically.

Fig. 11 shows the angle of the infinite-line impedance as a function of the frequency.

A further check on the accuracy of the results is obtained from the data in Table VI. From this data values of Z_a as determined by direct measurement when $Z_o = 100.01 + j\ 0.00000$ are

FIG. 7.



obtained. Using equation (11) and the transmission constants given in the second portion of Table X for the same frequencies as those at which Z_a was measured, the values of Z_a can be computed. A comparison of the computed and the directly measured

values can then be made. Table XII contains the results obtained by the two methods. In place of Z_a itself, the two components of its reciprocal are tabulated.

$$\frac{1}{Z_a} = g_a + j\omega C_a.$$

The greatest deviation between observed and computed values is slightly over two per cent., which is an amount at least four times what might reasonably be expected to be the possible error

TABLE XII.

Comparison of Measured and Computed Admittances when $Z_0 = 100.01 + j\ 0.000$. From data obtained at Fort Lawton end.

f	g_a measured	g_a computed	$10^6 C_a$ measured	$10^6 C_a$ computed
199.3	0.006200	0.006155	1.848	1.822
257.9	0.006431	0.006382	1.838	1.816
400.6	0.007236	0.007106	1.777	1.744
596.3	0.008816	0.008668	1.641	1.623
772.6	0.01062	0.01051	1.464	1.477
1008.6	0.01317	0.01319	1.164	1.192
1295.6	0.01561	0.01577	0.7752	0.7788

in the observations. This discrepancy, as well as the small, consistent deviations between the curves representing the line properties as determined from the two ends of the cable, undoubtedly arise from the fact that the cable is not homogeneous throughout its length. It is made up of two pieces, each having the same specifications as the other, but the two parts undoubtedly having slightly different properties because they were manufactured at different times. Such an explanation is sufficient to account for the differences observed, in view of the fact that the formulæ for the reduction of the observations presuppose complete uniformity. As they stand, the experimental results are undoubtedly of greater accuracy than can be hoped for in any analysis relating the observed electrical properties of the system to the fundamental physical constants and the dimensions.

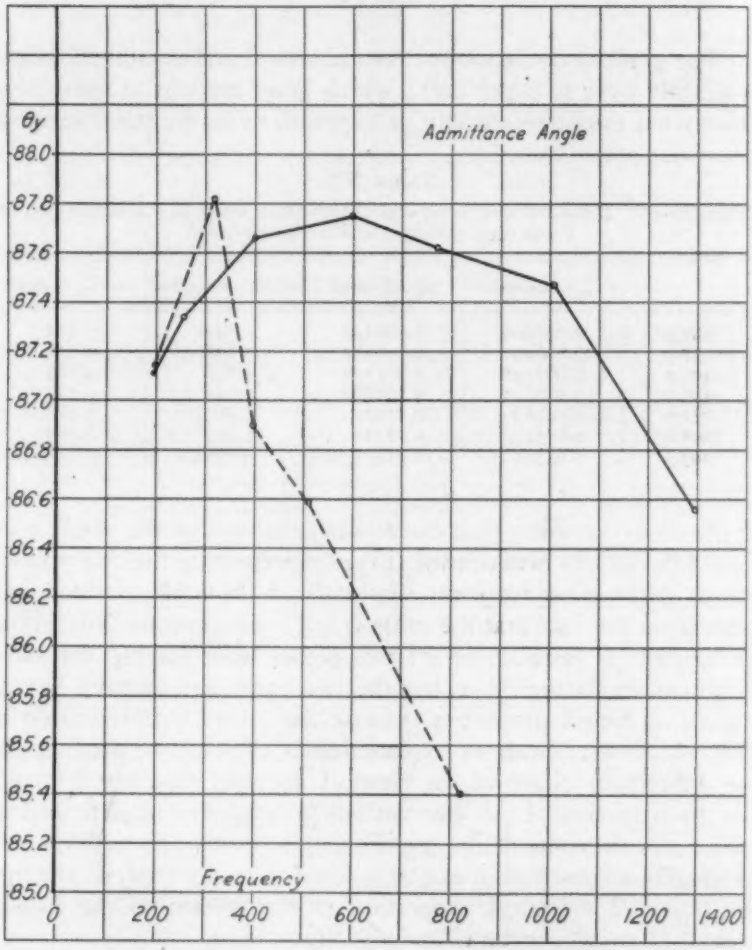
ANALYSIS OF RESULTS AND TRANSMISSION CALCULATIONS.

An examination of the results given in the foregoing reveals important general facts. Without going into a detailed, rigorous

analysis of the whole problem, some things can be found out which are of general approximate application.

The resistance, as expected, increases with the frequency.

FIG. 8.



At the frequencies employed, only a very small increase in resistance should result from the so-called skin effect in the main conductor itself, so that the observed increase, which is considerable, must arise from causes associated with the steel armor and the

surrounding water. The total resistance as observed is expressible as

$$r = r_o + \phi(\omega) \tag{11}$$

in which

r_o = direct-current resistance

and

$\phi(\omega)$ = an increasing function of ω whose value is zero at zero frequency.

The direct-current resistance depends only upon the conductor itself, while the increase in resistance, $\phi(\omega)$, depends only upon the surroundings of the conductor. All submarine cables are subjected to similar water immersions, and also are similarly-arranged combinations of dielectric and steel armor. The increase in resistance, $\phi(\omega)$, should then be approximately the same for most cables, regardless of what r_o may be.

When it is assumed that the increase in resistance is accounted for by the presence of a definitely localized short-circuited system in the vicinity of the main conductor, the equation for the apparent resistance takes the form (see Univ. of Calif. Publ. in Engineering, vol. i, "Alternating and Transient Phenomena in Coupled Electric Circuits," p. 171).

$$r = r_o + \frac{1}{a + \frac{b}{\omega^2}}$$

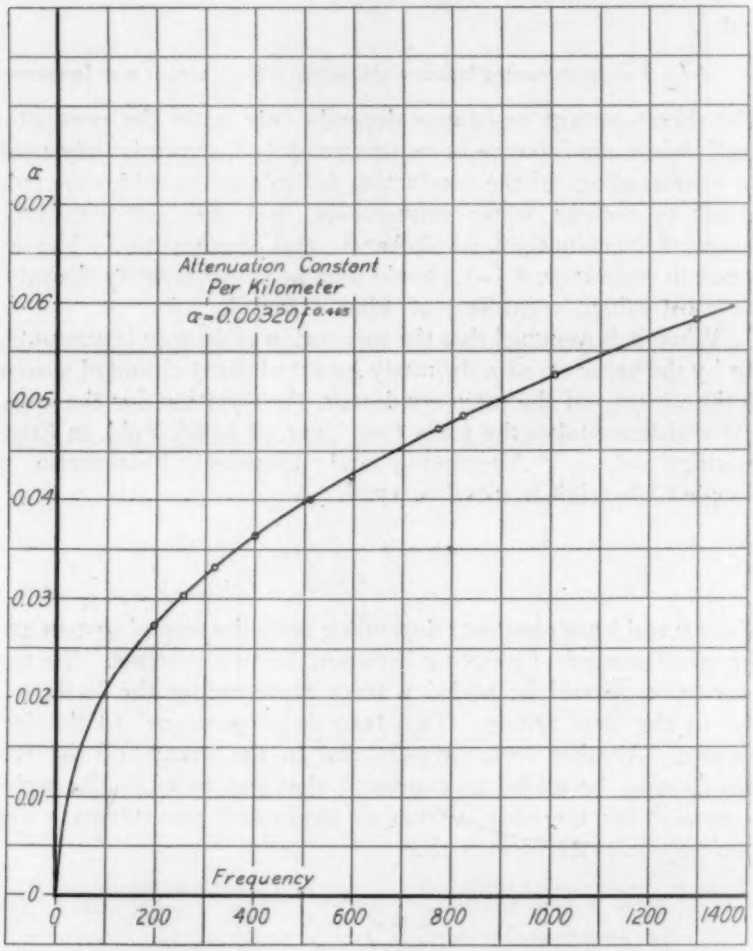
where a and b are constants depending upon the second system and the electromagnetic coupling between the two systems. To this expression should be added a term representing the hysteresis loss in the steel armor. This term is proportional to the frequency. Another term proportional to the square of the frequency may be added to represent the first term in the series expansion for the eddy-current or skin-effect phenomena. The final approximate form is then

$$r = r_o + \frac{1}{a + \frac{b}{\omega^2}} + c\omega + d\omega^2 \tag{12}$$

The observed data can be very well represented by this equation when the constants a, b, c, and d are determined by least-square methods. This shows that as far as the one quantity r is concerned, the hypothesis just made offers a satisfactory explanation

for the phenomena, but even so, this information does not aid materially in predetermining the resistance change for different sizes and kinds of cables. This latter requires that the effective

FIG. 9.

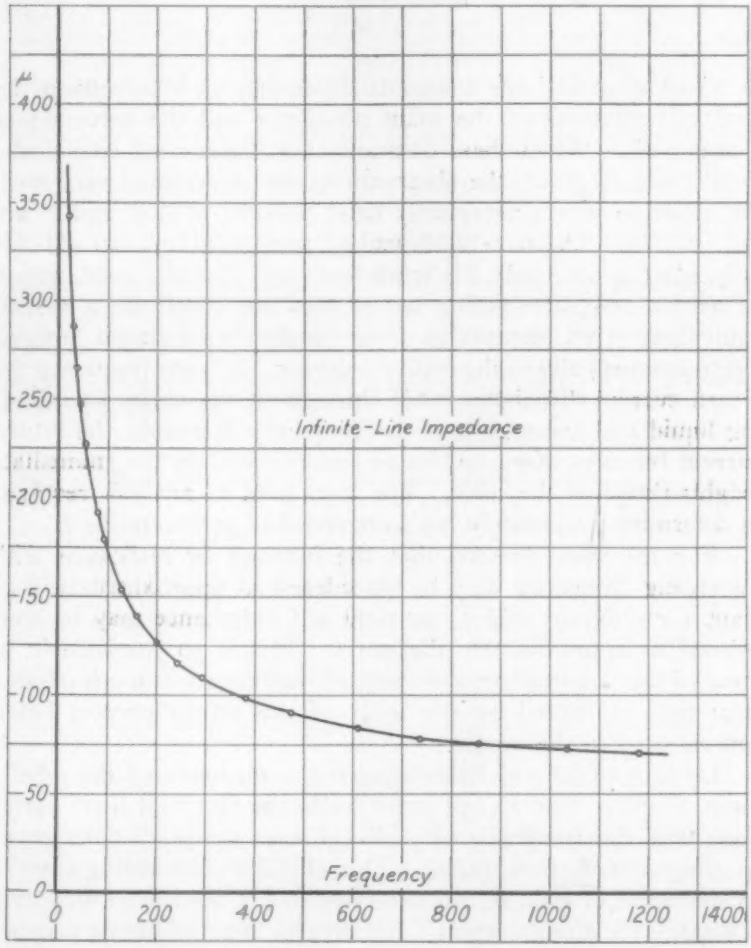


resistance be expressed in terms of the fundamental properties of the different components of the system. Without such detailed analysis, about the best that can be done is to accept equation (11), with $\phi(\omega)$ as determined from the data submitted. The

observed increase is approximately 1.7 ohms per kilometre, at a frequency of 1300 cycles per second.

The total apparent self-inductance is determined by those factors which determine the change in resistance. The percentage

FIG. 10.



error in estimating the total self-inductance for any cable will then be much greater than that in estimating the total resistance, because the total resistance contains a constant component which is capable of accurate determination at the time of manufacture.

If the surroundings of the main conductor be again considered as constituting a definite closed electrical path, the equation representing the total self-inductance as a function of the frequency will be of the form (see the above-named reference),

$$L = L_o - \frac{1}{a' + \frac{b'}{\omega^2}} \tag{13}$$

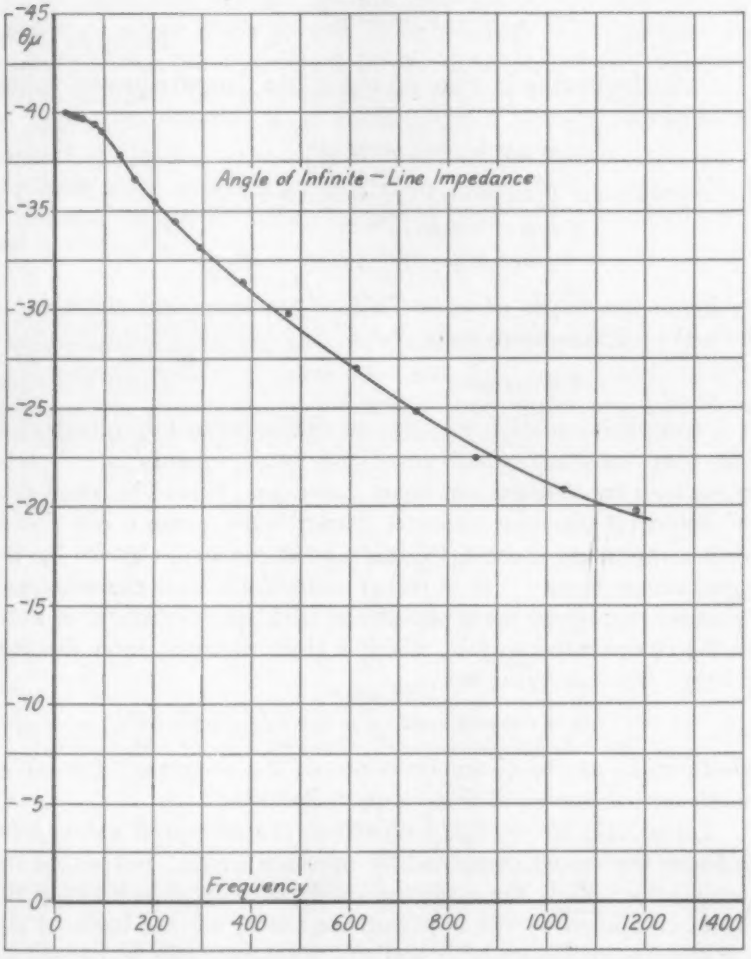
in which a' and b' are constants depending as before upon the electrical relations of the main conductor and the surrounding closed path. When these constants are determined empirically from the data given, the observations are represented very well, but relations which necessarily exist between a, b, a' and b' are not fulfilled. The non-fulfillment of these relations can indicate only what is obviously the truth—namely, that the combination of armor and surrounding water does not constitute a system equivalent in all respects to some simple closed circuit coupled electromagnetically to the main conductor. At zero frequency the return current distributes itself throughout the entire surrounding liquid and armor, but as the frequency increases, the return current becomes more and more concentrated in the immediate neighborhood of the cable. The same kind of analysis required to determine r accurately is also required to predetermine L.

For the same reasons that the increase in resistance with increasing frequency may be considered as approximately constant for different cables, the total self-inductance may be considered as approximately the same. This is so particularly in view of the fact that the observed self-inductance is much greater than that calculated on the basis of the return current being concentrated in the armor.

Little is to be said concerning the components of the admittance Y, other than to call attention to the fact that their variations with the frequency very closely meet the predictions given in the opening paragraphs. The effective alternating-current conductance, or leakage, is scarcely related to the simple dielectric resistance for direct current. It increases in approximate proportion to the frequency so that, with a practically constant capacity, the phase angle of Y is very nearly constant. For frequencies up to 1300 cycles per second, the change in the total effective capacity is only a few per cent.

When the four fundamental electrical constants are combined into the transmission constants given in Table X, marked discrepancies are to be noted between the experimental results and

FIG. 11.



those given by the ordinary cable theory. The usual analyses of the performances of cables acted upon by alternating currents have neglected the self-inductance and leakage (effective alternating-current) and have also assumed r and C to be constant and

equal to their respective zero-frequency values. Such theory leads to the simple expressions

$$\left.\begin{aligned} \beta = a &= \sqrt{\tfrac{1}{2}\,\omega\, r_o\, C_o} \\ u &= \sqrt{\frac{r_o}{\omega\, C_o}}\,;\theta_u = -45^\circ. \end{aligned}\right\} \tag{14}$$

If, from the curves in Figs. 4 and 7, the zero-frequency values be taken as

$$r_o = 4.66,\ C_o = 0.277 \times 10^{-6}$$

the approximate equations (14) become

$$\left.\begin{aligned} \beta = a &= 0.002014\, f^{0.5000} \\ u &= 1636 f^{-0.5000}\ ;\theta_u = -45^\circ. \end{aligned}\right\} \tag{15}$$

From the values of a, in Table X, an empirical equation as derived by least-square methods is

$$a = 0.00320\, f^{0.405} \tag{16}$$

It is from this equation that the smooth curve in Fig. 9 is drawn. The very satisfactory nature of the measurements is indicated by the way the observations lie on the curve. It is to be noted that the empirical equation makes a proportional to the 0.405 power of the frequency instead of the 0.5000 power as given by the approximate theory. It is rather remarkable that the empirical equation represents the observations with such accuracy, in view of the complicated way in which a truly depends upon the frequency. Its true value is

$$a = \text{real portion of } \sqrt{(r + j\,\omega\, L)\ (g + j\,\omega\, C)}$$

where, r, L, g, and C are functions of the frequency (or ω) as shown by the curves in Figs. 4 to 7, inclusive.

Table XIII shows for comparison the measured values of a and also the values computed by equation (15). For all of the frequencies shown, the observed values of a are smaller than the values computed by the approximate theory on the basis of the zero-frequency values of r and C. This can only be caused by the self-inductance, L, since the per cent. increase of resistance with frequency is much greater than the per cent. decrease in capacity at any frequency. This fact is readily appreciated after inspecting Table IX, where the angle of the impedance Z is seen

to reach 45 degrees at a frequency of 1300 cycles per second, instead of being 0 as given by the approximate theory. Table XIII also contains the observed and the calculated values of the infinite-line impedance. Because of the increase in r with frequency and also because of the self-inductance, the observed values of u are much greater than the approximate calculated values. Since the amount of power delivered to the cable at a given voltage is inversely proportional to u, and since the safety of the cable requires that the impressed voltage be definitely limited, it appears impossible to safely supply as much power to the cable as is indicated by the approximate calculations. If the impressed voltage be e, then the power input to the long cable is

$$P = \frac{e^2}{u} \cos \theta_u \qquad (17)$$

The approximate theory gives $\theta_u = -45$ degrees, a constant, but the experiments show that θ_u is very much less numerically than 45 degrees when the frequency reaches 1000 cycles per second, or beyond. As an illustration, if the impressed emf. be limited to 50 volts, the power inputs, as based upon the observed and calculated values of U, are, for a frequency of 1295.6 cycles per second,

$$P_{obs} = \frac{50^2}{65.33} \cos\,(-20.96^\circ) = 35.7 \text{ watts}$$

$$P_{cal} = \frac{50^2}{45.5} \cos\,(-45.0^\circ) = 38.9 \text{ watts.}$$

TABLE XIII.

Comparison of the Measured Values of the Transmission Constants and the Values Calculated by the Approximate Theory which Neglects L and G.

f	a obs.	a cal.	u obs.	u cal.	θ_u obs.
199.3	0.02730	0.02843	129.0	115.9	−35.7°
200	0.02723	0.02848	128.1	115.7	−35.7°
257.9	0.03032	0.03234	115.6	101.9	−34.4°
320	0.03312	0.03602	105.5	91.4	−32.6°
400	0.03620	0.04027	97.0	81.8	−30.9°
400.6	0.03635	0.04031	98.0	81.7	−31.5°
512	0.03995	0.04556	88.6	72.3	−28.7°
596.3	0.04234	0.04917	84.6	67.0	−28.5°
772.6	0.04717	0.05598	77.0	58.9	−26.4°
824	0.04843	0.05781	76.4	57.0	−23.7°
1008.6	0.05263	0.06394	70.4	51.5	−24.0°
1295.6	0.05822	0.07248	65.3	45.5	−21.0°

Even though the calculated impedance is much lower than the observed, the calculated power is not much larger than the observed because of the fact that the true power factor (cos–20.96°) is considerably greater than the calculated power factor (cos–45°).

As an illustration of the use of the foregoing data, calculations relative to the possibilities of signal transmission by alternating currents will be shown. The receiving-end condition which insures the reception of maximum power is that the load impedance Z_o be equal in scalar value to u, and also that it have an angle equal to, and opposite in sign, to θ_u. (See page 221, "Electrical Phenomena in Parallel Conductors," vol. i.) The calculation of the transmission phenomena is much simplified, however, when it is assumed that $Z_o = U$. When this is the case, the received power is slightly less than when the above optimum relation is fulfilled, but in a system with such an extremely low efficiency as a cable, this small difference is negligible. The general formula relating input voltage E and received voltage E_o is

$$E = E_o (\cosh Vl + \frac{U}{Z_o} \sinh Vl) \tag{18}$$

When $Z_o = U$, this reduces to

$$E = E_o (\cosh Vl + \sinh Vl) = E_o \varepsilon^{Vl} \tag{19}$$

Since, in this problem, it is only the effective scalar values of voltage which are of interest, the rotation of the vectors as produced by the imaginary portion of Vl may be neglected, giving

$$e = e_o \varepsilon^{al} \text{ or } e_o = e\varepsilon^{-al} \tag{20}$$

as the equation for scalar values when there is no reflection at the load end ($Z_o = U$).

As stated previously, e is limited by considerations of safety to 50 volts. Present possibilities in the construction of vacuum-tube amplifiers are such that an electromotive force of 10^{-7} volts is about the minimum value which will produce satisfactory signals at frequencies between 50 and 1500 cycles per second. By taking $e = 50$ and $e_o = 10^{-7}$, and using equation (20), the greatest distance over which signals can be transmitted satisfactorily can be calculated when a is known. The equation is

$$l = \frac{1}{a} \ln \frac{e}{e_o} = \frac{1}{Ma} \log \frac{e}{e_o} \tag{21}$$

where M = modulus.

The power input may be computed by equation (17).

Table XIV contains the results of calculations made for the Alaskan cable whose properties have been given in the foregoing. For this cable, since

$$a = 0.00320\ f^{0.405},$$

equation (21), after substituting 5×10^8 for $\frac{e}{e_0}$, becomes

$$l = \frac{6259.4}{f^{0.405}}$$

$$\log l = 3.79653 - 0.405 \log f \qquad (22)$$

The last column contains values of the distance for which $\varepsilon^{al} = 10$, or those distances in which the voltage decreases by a factor $\frac{1}{10}$. If l_1 designate this distance, then

$$l_1 = \frac{1}{Ma} \qquad (23)$$

TABLE XIV.

Transmission Data for Alaskan Cable.

Calculated from observed properties for $e = 50$ and $e_0 = 10^{-7}$ volts, u and θu from Figs. 10 and 11.

f	α per km.	u ohms	θ_u deg.	P watts	l km.	l_1 km.
50	0.01561	237	−39.7°	8.1	1284	147.6
100	0.02066	172	−38.8°	11.3	969	111.4
200	0.02736	126	−35.5°	16.1	732	84.2
300	0.03224	107	−33.0°	19.6	621	71.4
400	0.03622	96	−30.8°	22.4	553	63.6
600	0.04269	83	−27.1°	26.8	469	53.9
800	0.04796	76	−23.8°	30.1	418	48.0
1000	0.05250	72	−21.2°	32.4	382	43.9
1200	0.05652	70	−19.3°	33.7	354	40.7

It is hardly desirable to use frequencies below 50 cycles per second, for then in rapid signaling, each signal element would contain too few complete cycles to permit of selectivity in reception. For this particular cable, if 50 cycles per second be considered as the lowest usable frequency, then the greatest distance over which this method of signaling will produce 10^{-7} volts at the receiving end is 1284 kilometres (approximately 800 miles). In all cases the amount of power required for sending is small.

Description of actual trials of this method of signaling is given later.

As a further illustration of the foregoing analyses, calculations for a typical Atlantic cable will be attempted. For this illustration the cable described by Squier, "On an Unbroken Alternating Current for Cable Telegraphy," Proceedings of the Physical Society of London, vol. xxvii, Part V, page 553, has been chosen. The data given for it are

Length = 2164 nautical miles.
Total resistance = 4895 ohms.
Total capacity = 914.1 microfarads.
The dielectric is gutta percha.

Taking from Bowditch, 1918, the value 6080 feet per nautical mile, the above data gives for the zero-frequency properties

$r_0 = 1.2206$ ohms per kilometre.
$C_0 = 0.22794$ microfarads per kilometre.
Total length = 4010.3 kilometres.

This is all of the data available. Approximate values of the four fundamental electrical properties at different frequencies must be found in order to calculate the transmission constants.

The capacity may be considered as constant, independent of the frequency, since this was found to be very nearly the case for the Alaskan cable. For the Alaskan cable the angle of the admittance, θ_y, was found to be practically constant, with a mean value of 87.0 degrees. This is for a rubber insulation, which undoubtedly is poorer than a gutta-percha insulation. It is probable that for the latter an angle of 88 degrees would be nearer the truth, but this cannot be definitely asserted without some comparative study of the two kinds of dielectric. The value of 88.0 degrees will, however, be accepted as the basis for this calculation. The admittance then is

$$Y = (\omega C \operatorname{cosec} 88^\circ) \angle 88.0^\circ$$
$$= \omega C \cot 88^\circ + j\omega C \qquad (24)$$

since $C = C_0$

For the resistance, the direct-current value r_0 increased by $\phi(\omega)$, as determined for the Alaskan cable, is the best approximation possible. $\phi(\omega)$ can be found for any frequency from Fig. 4 by subtracting the direct-current value (4.660 ohms) from the

appropriate ordinate of the curve. For the self-inductance the values given by Fig. 5 are the only ones available to apply to the problem in hand.

Table XV gives the quantities required in the calculation of the transmission constants. In it

$\phi(\omega)$ was taken from Fig. 4.
$r = 1.2206 + \phi(\omega)$.
L was taken from Fig. 5.

The table also contains the scalar values and angles of the derived quantities Z and Y.

TABLE XV.

Approximate Values of Cable Properties for Atlantic Cable, Based upon its Direct-current Resistance and Capacity and the Alaskan Cable Data.

$C = 0.22794 \times 10^{-6}$ farads per km.
$r_0 = 1.2206$ ohms per km.
$\theta_y = 88.0$ degrees.

f	$\phi(w)$	r	L	Z	Y
0	0	1.22	.....	$1.22/0°$	.....
50	0.07	1.29	0.00144	$1.37/19.3°$	$0.0000717/88.0°$
100	0.30	1.52	0.00134	$1.74/29.0°$	$0.0001433/88.0°$
200	0.73	1.95	0.00121	$2.47/38.0°$	$0.0002866/88.0°$
300	0.95	2.17	0.00112	$3.03/44.2°$	$0.0004299/88.0°$
400	1.11	2.33	0.00105	$3.52/48.6°$	$0.0005733/88.0°$
600	1.35	2.57	0.00095	$4.41/54.3°$	$0.0008600/88.0°$
800	1.54	2.76	0.00088	$5.21/58.0°$	$0.001146/88.0°$
1000	1.71	2.93	0.00083	$5.98/60.7°$	$0.001433/88.0°$
1200	1.86	3.08	0.00080	$6.77/63.0°$	$0.001720/88.0°$

By using equation (6) in conjunction with equation (24) and the values given in Table XV, the transmission constants a, u, and θu are found to be as given in Table XVI. The distance l is calculated by equation (21) for $e = 50$ and $e_0 = 10 - 7$ volts. The power P is calculated by equation (17). The last column contains the quantity l_1, the distance over which the voltage and current change by a factor $\frac{1}{10}$. l_1 is given by equation (23).

Fig. 12 shows the quantities given in the table. The values of a are represented with sufficient accuracy by the equation shown on the curve. The curves, naturally, are similar to those for the Alaskan cable. The attenuation is much less and, on

TABLE XVI.

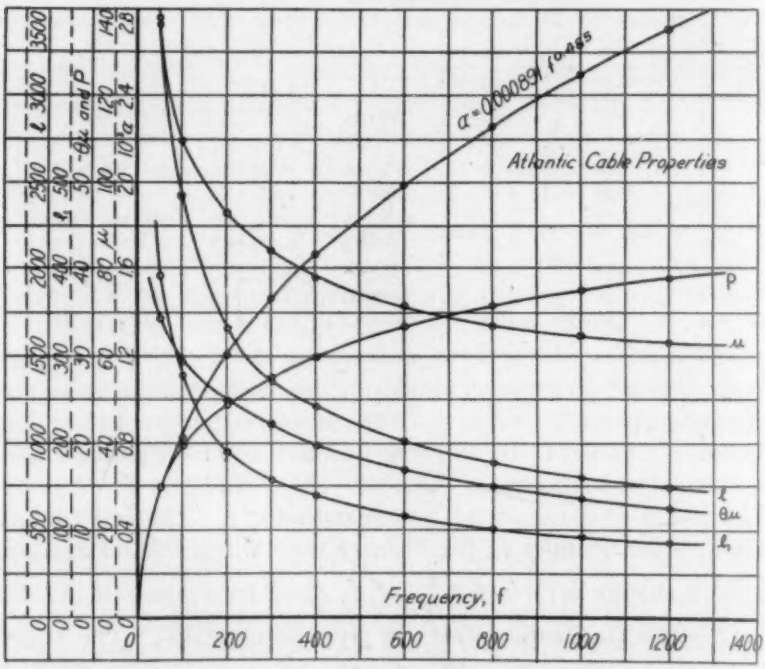
Calculated Transmission Data for Atlantic Cable.

From data in Table XV and for $e = 50$ and $e_0 = 10^{-7}$ volts.

f cyc.	α per km.	u ohms.	θ_u deg.	P watts	l km.	l_1 km.
50	0.00587	138	−34.3°	14.9	3415	393
100	0.00825	110	−29.5°	19.8	2429	279
200	0.01210	93	−25.0°	24.4	1656	190
300	0.01461	84	−21.9°	27.6	1371	158
400	0.01663	78	−19.7°	30.0	1205	138
600	0.01988	72	−16.8°	33.4	1008	116
800	0.02258	67	−15.0°	35.8	887	102
1000	0.02499	65	−13.7°	37.6	802	92
1200	0.02706	63	−12.5°	38.9	740	85

account of the lower resistance and consequent greater proportionate effect of the self-inductance, the angle of the infinite-line

FIG. 12.



impedance is more nearly zero. At 50 cycles per second, the maximum workable distance is found to be 3415 kilometres. This

is on a basis of 10^{-7} volts at the receiving end. The total length of this cable across the Atlantic is 4010 kilometres, so that it appears that the scheme of signaling with alternating currents is just possible for this cable. A slight decrease in frequency would decrease the attenuation sufficiently to still leave 10^{-7} volts at the full distance of 4010 kilometres. Since $l_1 = 393$ km. for $f = 50$ cycles per second (this being the distance for a 10-to-1 ratio of voltage or current), an improvement in the amplification at the receiving end by

$$\log^{-1}\left(\frac{4010 - 3415}{393}\right) = 33$$

times would also suffice to make transmission at a frequency of 50 cycles per second possible.

The above results should be highly significant in suggesting improvements in the already overworked Atlantic cables. The errors arising from the approximate manner of finding the cable properties should not be sufficient to vitiate the above conclusions.

TRIALS OF ALTERNATING CURRENT TRANSMISSION.

In addition to the measurements of the cable properties as described in the foregoing, a number of trials were made of the transmission of alternating currents over cables, both over the long cable between Sitka, Alaska, and Seattle, Washington, and over shorter cables between various towns in southeastern Alaska. The results which could be obtained in tests of this kind were, of course, entirely dependent upon the degree of amplification which was obtained in them. As it naturally was impossible, in the limited time available for this work, to do a great deal towards the development of powerful low-frequency amplifiers, the results here given cannot be considered as the best possible.

The first trials were made over the long cable and, as a preliminary step, calculations based upon the fundamental cable properties as previously determined, were made in order to ascertain approximate values of received voltage at the different frequencies. The total cable length between Sitka and Seattle is 1751 kilometres (1088 miles). The impressed electromotive force, both as used in the tests and in the calculations, was 50 volts. The results of the calculations are given in Table XVII, in which

the received voltage e_0 is that which occurs when the load impedance equals the infinite-line impedance U. The empirical equation for the attenuation constant α was used. At these very low frequencies no observations had been made to determine the cable properties, so that the empirical formula serves as a means of interpolating between the zero-frequency value zero and the value of α found at 200 cycles per second. For such low frequencies as are involved, the empirical equation for α gives values greater than does the approximate equation (15), whereas the reverse is true at the higher frequencies shown in Table XIV. The following data shows the differences between the two equations for the frequencies under consideration.

f	$\alpha = 0.00320\, f^{0.495}$	$\alpha = 0.00201\, f^{0.500}$
cycles per second	Empirical	Approximate
10	0.0081	0.0064
15	0.0096	0.0078
20	0.0108	0.0090
25	0.0118	0.0101
30	0.0127	0.0110
35	0.0135	0.0119
50	0.0156	0.0142

The difference between the two values is as much as 20 per cent. at the lowest frequency. By equating equations (15) and (16) and solving for f, the frequency at which both equations give the same result is found to be 65 cycles per second. It is probable that at the lowest frequencies the true value of α is nearer to that given by the approximate equation than to that given by the empirical equation, because at the low frequencies the self-inductance does not play an important part. The true value of α and the empirical equation become asymptotic before a frequency of 200 cycles is reached, because at this frequency the measurements began and the empirical equation was deduced so as to fit the facts. The conclusion is certain that, at frequencies below 50 cycles per second, the empirical equation gives values of α which are too high. It is equally certain then, that the conditions represented in Table XVII are at least as bad, if not worse, than the true state of affairs. The true values of e_0 may be several times those shown.

For the trials of transmission over the long cable, the generator and sending apparatus was installed at Sitka and the amplify-

ing and receiving apparatus at Seattle. For amplification a tuned, vacuum-tube amplifier with any desired number of stages up to six was developed. It consisted of the standard type (V.T.–2) Signal Corps transmitting tubes interconnected by transformers which were arranged to be tuned by adjustable condensers connected to their secondary windings. A voltage amplification of from 6 to 8 per stage was obtained at frequencies of from 20 to 40 cycles per second. For six stages a total voltage amplification of from 50,000 to 250,000 was thus obtained. Because of the fact that no success attended any of the trials made over this long cable, a detailed description of the amplifier and receiving apparatus is not necessary here.

TABLE XVII.

Calculated Attenuation Constant and Received Voltage for Seattle-Sitka Cable.

$\alpha = 0.00320\, f^{0.405}$, $e_0 = e\,\varepsilon^{-al}$, $l = 1751$, $e = 50$.

f	al	e_0
10	14.2	33.0×10^{-6} volts
15	16.8	2.61×10^{-6} volts
20	18.8	0.328×10^{-6} volts
25	20.6	0.0553×10^{-6} volts
30	22.2	0.0114×10^{-6} volts
35	23.6	0.0027×10^{-6} volts
50	27.3	0.00007×10^{-6} volts

It was at first planned to use a telephone receiver to detect signals of audible frequency, but a consideration of the results given in Table XVII showed conclusively that it would be hopeless to detect received currents of frequencies above 35 cycles per second and that, therefore, a signal of audible frequency could not be obtained. For use over the range of frequencies between 15 and 35 cycles per second a vibration galvanometer was selected. This instrument was kindly loaned for the duration of the experiments by the Electrical Engineering Department of the University of Washington. In addition to high sensitivity at the low frequencies it had the additional advantage of being very selective as to frequency, so that it should be an aid in minimizing the effect of "stray" disturbances. The galvanometer resistance was 49 ohms; excellent adjustment of sensitivity was obtained by shunting its terminals with a known resistance.

A typical record of one of the numerous trials is given here:

Date of trial, August 23, 1919.
Sending station, Sitka, Alaska, cable office.
Impressed electromotive force, 50 volts.
Frequency, 20 cycles per second.
Approximate input current, 0.15 amperes.

At Seattle, with the amplifier and galvanometer placed in a room about 15 metres distant from the cable office, it was found necessary to have all sounders and relays shut off because of the disturbances transmitted electromagnetically from them. When these instruments (sounders and relays) were not in operation, the amplifier by itself was entirely quiet, with no tendency to oscillate, as indicated by the galvanometer remaining steadily at zero. The amplifier and galvanometer were both tuned to 20 cycles per second.

With the cable connected to the input terminals of the amplifier, and when voltage was not impressed upon the cable at Sitka, the galvanometer gave a very unsteady deflection, averaging 2 centimetres on the scale when the galvanometer terminals were shunted by 0.2 ohms. This shunt reduced the galvanometer sensitivity to about $\frac{1}{250}$ of normal. No change in the unsteady deflection could be detected when alternating current was sent from Sitka. The observed deflection could only have been caused by "stray" electromotive forces induced in the cable system by street-car and power circuits, or by some natural, but obscure, magnetic or electric effects in the long cable itself. The cable office being in the midst of a busy portion of Seattle, it is known that the former influences were present, while it is not likely that natural magnetic or electrical variations, of such abruptness as to affect a tuned vibration galvanometer, connected to the cable through several stages of transformers, are to be found. Accurate information concerning this matter is needed, however. Calibration of the amplifier and galvanometer at the time of this test showed that at 20 cycles per second an input to the amplifier of 10^{-3} volts was necessary to produce the observed 2-centimetre deflection. The stray phenomena at the office cable terminals were, then, of this same order of magnitude, *viz.*, 10^{-3} volts, and probably were several times this amount, since in the calibration the frequency supplied was steady and equal to that

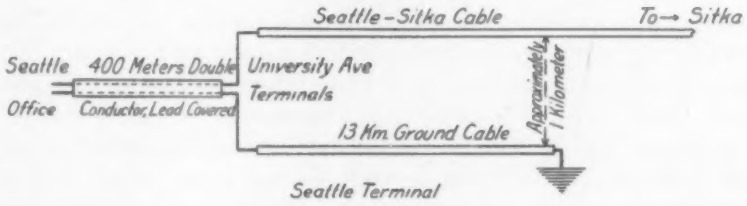
for which the galvanometer was tuned, which is not the case with the strays. From Table XVII it is seen that the received voltage to be expected is only 0.328×10^{-6} volts, a value only $\frac{1}{3000}$ of that arising from strays. It would obviously be impossible, therefore, to detect the small steady deflection in the midst of erratic stray deflections 3000 times its magnitude. With the galvanometer unshunted, or at normal sensitivity, the deflection for the steady alternating voltage of the above amount would have been

$$250 \times \frac{0.328 \times 10^{-6}}{10^{-3}} \times 2 \text{ cm.} = 0.16 \text{ cm.}$$

In the absence of stray disturbances, this amount could easily have been detected.

Since so much stray disturbance was encountered in the Seattle office building, it was decided to remove the amplifier and galvanometer to the shore-end of the sea cable, thereby eliminating about 400 metres of double-conductor, lead-covered cable between the shore-end and the Seattle office. Fig. 13 shows the

FIG. 13.



arrangement of the cable and ground connections at the Seattle end. Ground connection was made through approximately 13 kilometres of the standard type of submarine cable running out from Seattle into Puget Sound. The outer end of this cable and the attached ground contact is about 1 kilometre distant from the main Sitka-Seattle cable. Between the University Avenue shore terminal of the sea cable and the water, both the Sitka and the ground cables pass for approximately 100 metres beneath pavements and wharves.

With the amplifier and galvanometer adjusted as in the preceding test it was found that, when connection was made to the University Avenue cable terminals, a shunt resistance to the

galvanometer of 12 ohms was required to reduce the deflections caused by stray disturbances to 2 centimetres. Since for this same deflection a shunt of 0.2 ohms was required in the Seattle office building, it appears that the disturbances coming from the cables are only about $\frac{1}{50}$ of those reaching the office. According to the calibration cited, the above corresponds to about 20×10^{-6} volts, which, as stray disturbance, is still about 60 times the alternating voltage of this same frequency which could be received from Sitka.

A series of results similar to those given above were obtained at different times, after which it was decided that it would be useless to attempt reception at the Seattle end. On account of the limited time available it was not possible to interchange apparatus and thus attempt transmission in the opposite direction. The amplifier and galvanometer were taken to Sitka, however, and there it was found that, because of the absence of extensive city power systems, very little disturbance could be detected. The small disturbances which were observed could very well have been caused by a low-power alternating-current lighting circuit which passed within 50 or 75 metres of the testing room.

In any practical application of this method of alternating-current signaling, great care will be required to avoid any local sources of disturbances in those cases where, on account of great cable length, a high degree of amplification becomes necessary.

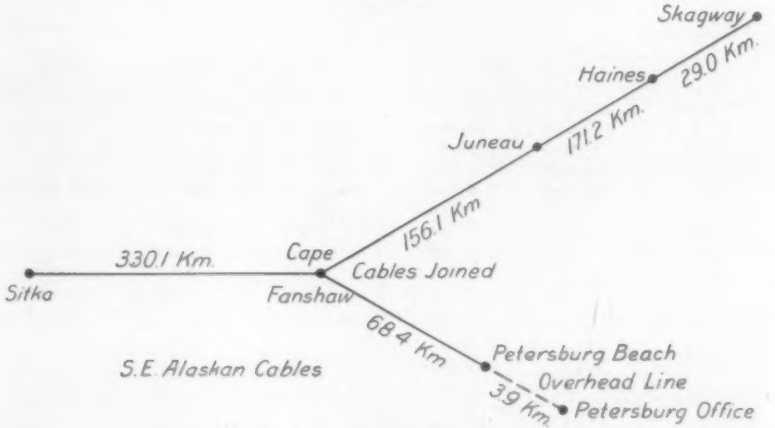
Because of the failure to transmit alternating currents over the long Sitka-Seattle cable, and because other work required the presence of the entire party in Alaska, arrangements were made to conduct further experiments with alternating currents over the shorter lengths of cable extending from Sitka to other points in southeastern Alaska. These tests occupied the first two weeks in October, 1919, and in them alternating currents of frequencies from 50 to 700 cycles per second were satisfactorily transmitted and received over distances from 300 to 700 kilometres.

For these trials the amplifier was altered slightly in order to meet the conditions imposed by the higher frequencies which could be transmitted over these shorter lengths of cable. In its modified form an amplification of approximately 14.5 per stage, throughout the above range of frequencies, was obtained. With

the four stages available, a total voltage amplification of 40,000, or a corresponding power amplification of 16×10^8, was thus available. This is the maximum amplification possible when the load, cable output, and amplifier input and output impedances are so related as to give the best results. During the tests it is probable that the total voltage amplification actually secured was only about 20,000 or 30,000 instead of 40,000, because the several cond tions required for maximum effectiveness could not be met exactly.

The cable network over which the experiments were made is as shown in Fig. 14, where the distances in kilometres between the various stations are shown. In the tests the generator was at

FIG. 14.



Sitka, while the amplifier and receiving apparatus were taken to the various points. At Cape Fanshaw the receiving set was connected to the Sitka cable after the other two branch cables had been disconnected. During all subsequent tests at the other points the three cables were joined at Cape Fanshaw, so that the received voltage was somewhat decreased because of the additional load imposed on the system by the branch cable. When the separate branches are of such length that reflected waves are negligible in comparison with the main waves, then the exact effect of this branching is to reduce all currents and voltages in the two branches to $\frac{2}{3}$ of the values they would have in the case of transmission over a single cable of a length equal to the distance between sending and receiving stations via the junction point. This reduc-

tion in voltage for all tests except that at Cape Fanshaw is taken account of in Table XVIII, which contains values of received voltages as calculated for the different points and different frequencies included in the experiments.

TABLE XVIII.

Calculated Values of Received Voltage.

For Cape Fanshaw, $e_0 = 50\, \varepsilon^{-al}$

For all others $e_0 = \frac{2}{3} \times 50\, \varepsilon^{-al}$

$\alpha = 0.00320\, f^{0.405}$

The values given are expressed in microvolts.

Frequency	Station and distance				
	Cape Fanshaw 330.1	Petersberg Beach 398.5	Juneau 486.2	Haines 657.4	Skagway 686.4
50	290,000	66,000	17,000	1,200	740
75	116,000	22,000	4,400	190	110
100	55,000	8,900	1,400	42	**23**
125	29,000	4,100	560	**12**	6.0
150	16,000	2,000	240	3.7	1.8
200	6,000	610	**56**	0.52	0.23
300	1,200	88	5.2	0.021	0.0082
400	320	**18**	0.75	0.0015	0.00053
500	100	4.6	0.14	0.00016	0.000051
700	**12**	0.46	0.0085	0.000004	0.00000095

In Table XVIII the values corresponding to the highest frequencies satisfactorily received at the several stations are printed in heavy type. Were the amplifier and telephone receiver used in connection therewith of the same sensitivity at the different frequencies, these limiting values of voltage would all be equal provided the empirical equation for the attenuation constant α truly represents the facts. Since this equation was determined so as to agree with the facts as determined by experiment, no error of consequence need be expected in the calculations. As a matter of fact, all of those limiting voltages shown in the table are nearly constant. Had time permitted of a greater number of observations and a calibration of the amplifier for each, it is likely that a still greater uniformity in these results would have been obtained. The average of the several figures shown gives

Average received voltage for good signals with 4-stage amplifier = 24 microvolts.

For receiving the signals a standard, high-impedance Baldwin radio head set with double receivers was used. By good signals are meant those which were distinctly audible with the telephone receivers lying on a table at a distance of one metre from the observer. With the telephones on the head in the ordinary manner, this gives very good signals, indeed.

With the receiving apparatus as used, it is unquestionable that a received electromotive force of 5 microvolts would in all cases produce signals of ample intensity. It is, further, entirely possible to construct an amplifier 50 or 100 times as powerful as the one used throughout these tests, because, for the one used, such apparatus as was available had to be used instead of apparatus especially designed for the purpose. In addition, the amplifier had to be carried about from place to place and set up hurriedly in whatever place could be found in the various cable offices. All of these things conspire to prevent the maximum effectiveness in the use of such an apparatus.

The only thing which could prevent the use of a considerably greater degree of amplification than that employed is excessive extraneous, or stray, disturbances. The experiences met with in these tests showed that trouble of this nature can be avoided by taking the proper precautions. The amplifier cannot be used in the vicinity of power systems, and the cable must not pass close to such systems. It is considered quite certain that most of the disturbances are produced by electromagnetic induction and earth currents arising from grounded systems; conditions which make effective shielding practically impossible. With a cable in the open sea or everywhere at a distance of at least 2 or 3 kilometres from overhead power systems or of 10 or 12 kilometres from earth-return power systems, no difficulties should be expected.

Accepting, then, 5 microvolts as a sufficient amount to produce good signals with the amplifier used, and further, accepting the possibility of 50 or 100 times the amplification actually attained, it becomes possible to produce good signals with a received electromotive force of from 5×10^{-8} to 10^{-7} volts. It is in this way that the basic value of 10^{-7} volts was obtained for use in the calculation of the data given in Tables XIV and XVI.

A summary of the notes taken during the several trials of alternating-current transmission and reception is given in the

following table. The data contained in Table XVIII should be considered along with these notes:

TABLE XIX.

Notes on Observations Taken in Trials of Alternating-Current Transmission.

Date of tests, October 1 to October 15, 1919.
Sending station, Sitka, Alaska.
Generator electromotive force, 50 volts.

AT CAPE FANSHAW (330.1 km.).

Juneau and Petersberg cables disconnected.
Using a standard, low-impedance, bi-polar telephone receiver, readable signals were obtained at 300 cycles per second without amplification. Very loud signals of this frequency were obtained with one or more stages of amplification.
At 500 cycles per second the signals were just audible without amplification. Good signals were received with 2 and 3 stages of amplification, and very loud signals with 4 stages.
At 700 cycles a very steady, clear note which produced excellent signals was obtained with 4 stages of amplification.

AT PETERSBURG OFFICE (402.4 km.).

All cables interconnected at Cape Fanshaw.
Amplifier installed at cable office, which connects with the beach end of the cable through 3.9 km. of overhead line. Ground connection at the office.
Excessive inductive interference from surrounding power circuits was encountered, which made tests at this location impossible.

AT PETERSBERG BEACH (398.5 km.).

Amplifier mounted in open air at the cable terminal.
Excellent reception with 2 stages at 150 cycles.
At 200 cycles very loud signals were obtained using 3 and 4 stages; strong signals at 300 cycles with 3 stages.
With 4 stages good signals were received at 400 cycles.
All of the tests were satisfactory in every respect. No trouble from stray disturbances was encountered.

AT JUNEAU (486.2 km.).

Amplifier installed in cable office. Some interference from power circuit, which produced a distinct hum in the receiver.
The 100-cycle note could be heard all over the room with 4 stages of amplification, was very good with 3 stages, and produced good readable signals with 2 stages.
At 150 cycles the power-line interference was disturbing, but very good signals were obtained with 4 stages of amplification.

At 200 cycles satisfactory signals were obtained, but the interference still persisted.

The 250-cycle note could be heard distinctly, but beats between it and some harmonic in the power system prevented satisfactory reading of signals. (In Table XVIII the limiting voltage for the Juneau test should, therefore, be considerably less than the 56 microvolts as given for 200 cycles.)

During the experiments at Juneau a satisfactory trial was made of receiving direct-current signals from Petersberg on the regular cable instruments and at the same time receiving 100-cycle signals from Sitka.

AT HAINES (657.4 km.).

At Haines direct connection with Sitka was established by connecting through the Juneau office, but the two cables are not normally operated in this way.

Very loud 50-cycle signals were received with 4 stages. For a duration of several minutes the regular station operator there read Continental Morse code signals at the rate of 15 words per minute, and in a further test of several minutes, at the rate of 25 words per minute with the greatest ease.

Excellent signals, both with 3 and 4 stages of amplification, were received at 100 cycles, and sending in Continental Morse code was easily read at a rate of 25 words per minute.

At 125 cycles the signals were distinctly audible with 4 stages of amplification, but too much interference from power sources was present to permit of clear reading. The power interference was of the same character as that observed at Juneau, and since the cables were interconnected through the office there, it is thought that the interference originated in the Juneau office and exposed cable. The attenuation of these interfering currents over the distance of 70 km. between Juneau and Haines would not be sufficient to make them negligible, because the incoming signals are attenuated in the same way.

Signals at 150 cycles were not readable on account of the interference.

AT SKAGWAY (686.4 km.).

Excellent signals at 50 cycles per second were received using 4 stages of amplifier. Whereas it had previously been somewhat doubtful if frequencies as low as 50 cycles per second would produce satisfactory telegraphic signals, the actual tests both here and at Haines showed that for a signaling rate as high as 25 words per minute, at least, this frequency serves as well as frequencies in the more sensitive region of audibility.

At 75 cycles the signals would have been perfectly satisfactory except for the interference from power circuits.

In the same way, 100-cycle signals were clearly audible with 4 stages of amplifier, but on account of the interference were not readable.

The signals were just audible at 150 cycles, and at 200 cycles nothing at all could be heard.

At Skagway, the cable comes in the sheath directly from the shore to the office through a trench of approximately 0.5 km. in length, passing near to power lines and transformers in the vicinity of the office.

Disturbances created at this point undoubtedly affected both the tests here as well as at Haines, in addition to disturbances arising at Juneau.

The data contained in the above notes serve to establish the limiting values of voltage shown in Table XVIII.

The results of the trials as described above, and particularly when considered in conjunction with the mathematical analysis and calculations given are such as to fully justify the statement that a very great increase is possible in the usefulness of a great majority of existing cable systems. Although it is something that had not been hoped for, the calculations nevertheless show that this method of signaling is applicable even to an Atlantic cable. If it should prove capable of superposing even one message on the existing duplex working of an Atlantic cable, the method would increase the working value of such a cable by 50 per cent. On cables shorter than this, of which there are very many, the increase in working effectiveness would be still greater, because of the greater range in frequencies which can be utilized.

ACKNOWLEDGMENTS.

In conclusion it is desired to render acknowledgment to a number of people through whose effective aid the work described in the foregoing was made possible.

First, to the Chief Signal Officer of the Army, Major-General George O. Squier, must be given the credit for recognizing that work of the kind described was desirable, and even necessary, and for authorizing the Signal Corps Research Laboratory to proceed with the experimental work.

In addition to the writer, the experimental party consisted of

Dr. Sylvan J. Crooker, Radio Engineer,
Mr. Lester J. Rich, Radio Laboratory Assistant,
Mr. Chance E. Bohner, M.S.E., U. S. A.,

and for a portion of the time,

Mr. George L. Greves, Assistant Professor of Electrical Engineering, University of California.

Needless to say, to them is due the credit for the expeditious accomplishment of the work undertaken.

Without the active interest and coöperation of Lieut.-Col. B. O. Lenoir, Officer-in-charge, Washington-Alaska Military Cable and Telegraph System, the work could not have been carried out. Although every effort was made not to interfere with the regular operation of the system, the experimental work could not but cause considerable inconvenience. Much of the burden of keeping this disturbance at a minimum naturally fell on the chief operators, John A. Perry, M.S.E., at Seattle, and Phil McQuillan, M.S.E., at Sitka. Their efforts are very much appreciated.

For the trials of alternating-current transmission in southeastern Alaska, the Forest Service very kindly placed their gasoline cruiser, " Ranger V.," at the disposal of the testing party, and at the same time authorized the Forester at Sitka, Mr. Geo. A. Peterson, to accompany the expedition. Mr. Peterson's inimitable qualities as a host made the two weeks spent aboard his vessel, going from place to place in the waters of southeastern Alaska, a delightful experience long to be remembered.

Phosphorus in Butter.—According to J. T. CUSICK (*Cornell University Agricultural Experiment Station Memoir 30*, pp. 153–187, 1920), approximately one-fourth of the total phosphorus of the cream is retained by the butter; the remaining three-fourths are lost in the buttermilk during churning, in the wash waters, and in the exudates which form during the process of salting. During storage, the organic phosphorus compounds are broken down into inorganic phosphorus compounds. The treatment of the milk and cream prior to churning influence the amount and the form of the phosphorus retained in the butter, and also determine how soon after storage the organic phosphorus compounds are transformed into inorganic compounds. Under certain conditions, bacteria are the controlling factors in producing chemical changes in the phosphorus compounds. Fishy flavor in butter is due to the decomposition of lecithin and the formation of trimethylamine; development of this flavor is always accompanied by an appreciable decrease in soluble organic phosphorus. Salt in butter has a marked effect in bringing about decomposition of the proteins during storage, even at a temperature of –10° C. The recently discovered, alcohol-soluble protein of milk also occurs in butter.

J. S. H.

Finger-prints as Evidence.—The Navy Department, Bureau of Navigation, has recently issued a bulletin giving summaries of a considerable number of cases in which courts have sustained the use of finger-prints in criminal trials. The pamphlet was compiled by J. H. Taylor, finger-print expert of the Identification Division of the Navy, the method being extensively applied in that service for the identification of deserters. Foreign as well as domestic cases are cited, the first case given being from India in 1905 (Emperor vs. Abdul Hamid), the charge being false personation. Reports are printed from several police headquarters in different parts of the United States, which show that police authorities regard the method as of great certainty and satisfactory application, when well-trained experts are employed. The following report taken from a number submitted by the Chief of Police of San Francisco—in which office both the finger-print and Bertillon systems are employed—will serve to show the practical value of the method.

July 11, 1916, Robert Roubles was arrested on charge of burglary. Finger-prints were found on a window at a private residence, and the prisoner was identified as the one who had committed the crime. His record was found in the police department under the name of Wesley Baldwin.

The method has undoubtedly great value, but unfortunately the criminal classes have largely resorted to wearing gloves and in this way eliminating the traces of the prints. H. L.

North America Third in Mountain Heights. (*U. S. Geol. Surv. Press Bull. No. 452,* July-August, 1920.)—North America ranks third among the continents in the heights of mountains. Asia has Mount Everest, of the Himalayas, which stands 29,002 feet above sea level, and South America has Mount Aconcagua, of the Andean system, which is 23,080 feet high. North America comes next with Mount McKinley, in Alaska, 20,300 feet, and Africa is fourth, with Kibo Peak, 19,320 feet. Mont Blanc, Europe's highest mountain, is 15,782 feet high, which is more than a thousand feet higher than any mountain in the United States outside of Alaska.

Cable Construction. (*Scientific American,* August 7, 1920, p. 121.)—Despite the great development of wireless telegraphy, submarine cables are still being constructed, and with the great increase in commercial and journalistic messages are still regarded as a necessary alternative to wireless, and by no means obsolete or likely to fall into disuse. In fact, a new cable to the Far East from Great Britain through the Mediterranean, involving a length of 7000 miles, is being laid section by section as ready, while the possibility of a new cable from Vancouver to Fanning Island is now being discussed.

INDUSTRIAL ALCOHOL.*

BY

BURNELL R. TUNISON.

U. S. Industrial Alcohol Company, New York City.

To the layman, the word alcohol merely signifies that constituent (ethyl alcohol, grain alcohol, ethanol) which imparts intoxicating properties to spirituous, vinuous, and malt beverages. He incorrectly defines industrial alcohol as the relatively small amount of alcohol which is used in pharmacy, in the compounding of drugs and the manufacture of various pharmaceutical preparations. As a matter of fact, according to the United States Bureau of Internal Revenue, it is estimated that almost 52,490,000 proof gallons of alcohol were used during the year 1918 exclusively for the manufacture of explosives and other war purposes. Since ethyl alcohol is commonly called grain alcohol, most people consider that it is made from grain, and that its manufacture further increases the world food shortage. In order to correct these very prevalent misconceptions as to alcohol for industrial purposes, an attempt will be made to explain some of the more important phases of industrial alcohol.

HISTORICAL.

While the history of industrial alcohol probably dates from the beginning of the development of industrial chemistry, this product has been of importance in the United States for only a few years. In nearly every country alcohol had been known for centuries as a component of many of the popular beverages before it became an article of industrial importance. Most nations had experienced the results of alcoholism and had levied taxes on alcoholic beverages for the purposes of obtaining revenue and to curb to some extent the indiscriminate use of such beverages.

Probably the first recognition of alcohol as such was by the alchemist Basilius Valentinus, who recognized in spirit of wine the chief product of fermentation. In 1689 the German physician and chemist Becker thought that fermentation was a process

* Communicated by the Author.

similar to combustion, on account of the similarity of the waste gases evolved. He also stated that only the different varieties of sugars were capable of alcoholic fermentation.

Although, little by little, knowledge was acquired concerning alcohol and alcoholic fermentation, it was not until the studies of Pasteur that any marked progress was made. This investigator carefully studied the specific properties of the yeasts and the nourishment, growth, and multiplication of their cells.

On account of the microscopic size of the yeast cells, definite knowledge concerning them was not obtained until the development of the modern microscope. Although early investigators had seen yeast cells, it was not until the microscope reached a high state of perfection that the organisms were systematically studied.

Traube, in 1858, explained that fermentation was due, not to the yeast cell itself, but to certain substances which were produced or secreted by these cells; however, this theory was discredited for many years. One of the many theories explaining alcohol formation was that sugar was taken in as food by the yeast, and alcohol and carbon dioxide were given off. Liebig held that sugar was mechanically decomposed as a result of the molecular motion, and that the yeasts themselves were a product of the reaction and not its cause.

Not until recent years was the theory set forth by Traube shown to be essentially correct. It is now believed that fermentation processes are due only indirectly to the cells themselves, and directly to enzyme action. These enzymes are formed by living yeast cells and act on the invert sugars in such a manner as to split them into alcohol and carbon dioxide.

Although Germany probably was the first to recognize the industrial value of alcohol, Great Britain was the first country which attempted to denature or methylate ordinary alcohol. For a number of years Great Britain had levied a tax on alcohol; and, in 1855, the use of methylated spirit for industrial purposes was authorized. This methylated spirit was exempted from the taxes which had been imposed on alcohol. The methylated or denatured alcohol was made by mixing 10 per cent. of commercial methyl or wood alcohol with ethyl alcohol. The methyl alcohol used for denaturing was a product which contained a certain

portion of acetone and other components which were difficult of separation.

In 1865 the Netherlands authorized the use of denatured alcohol for manufacturing purposes. A law giving greater freedom was enacted in 1872. The use of such methylated spirits, and the use of spirits for special purposes was subject to regulation by the Government.

France has permitted the use of denatured alcohol under a modified tax since 1872. The law was modified in 1881, with respect to the quality of the denaturant. In addition to the methyl alcohol, some heavy benzine and green dye were used. Other denaturants have since been authorized.

The use of tax-free alcohol for industrial purposes has been permitted in Germany since 1879. Several laws have been enacted since that time giving greater freedom of use, and adding additional formulæ for denaturing. Germany has authorized the use of many denatured alcohols and has stimulated the use of such alcohol by subsidy, etc., so that alcohol for manufacturing purposes is cheaper in Germany than in any other country. Undoubtedly this fact has had a tremendous influence on the development of the German chemical industries.

After some of the larger countries had enacted laws for the use of tax-free alcohol for manufacturing purposes, other countries were not slow in following their example. The use of tax-free alcohol for industrial purposes was authorized by:

Austria	in 1888
Italy	in 1889
Sweden	in 1890
Norway	in 1891
Switzerland	in 1893
Belgium	in 1896

The history of the taxation of alcohol in this country may be briefly summarized. On account of the need of revenue in the early days of the country, a tax on distilled spirits was imposed in 1791. Thomas Jefferson caused a repeal of this law in 1802. The expenses of carrying on the war with Great Britain led to the levying of a tax on spirits in 1813. This law was repealed in 1817; and no other tax was imposed until the time of the Civil War when a tax of 20 cents per gallon was levied. In 1868 this was increased to 50 cents; in 1872 to 70 cents; in 1875

to 90 cents; in 1894 to $1.10 per gallon, and that rate continued until 1917, when the tax was increased to $3.20 per proof gallon for beverage spirits and $2.20 for non-beverage variety.

Thus 95 per cent. undenatured alcohol for manufacturing purposes is taxed at the present time at the rate of $4.18 per gallon.

Limited exemptions have been provided at various times when taxes were levied. For instance, a law of 1878 authorized the Secretary of the Treasury to permit "any incorporated or chartered scientific institution or college of learning to withdraw alcohol in specified quantities from bond without payment of the Internal Revenue tax on the same, or on the spirit from which the alcohol has been distilled, for the sole purpose of preserving specimens of anatomy, physiology, or natural history belonging to such institution, or for use in its chemical laboratories." To this was attached a proviso that the application for a permit must be made by the President or Curator of the Institution and they were required to file a bond for double the amount of the tax on the alcohol to be withdrawn, with two good and sufficient securities.

In 1897 a careful and comprehensive investigation in this country and abroad of the question of tax-free alcohol for industrial purposes did not result in the passage of the bill under consideration. The investigation was continued and brought to an issue which resulted in the passage of the Denatured Alcohol Act of 1906. This law provided in part (Regulations 30—Revised—page 1): "From and after January first, nineteen hundred and seven, domestic alcohol of such degree of proof as may be prescribed by the Commissioner of Internal Revenue, and approved by the Secretary of the Treasury, may be withdrawn from bond without the payment of internal-revenue tax, for use in the arts and industries, and for fuel, light, and power, provided said alcohol shall have been mixed in the presence and under the direction of an authorized Government officer, after withdrawal from the distillery warehouse, with methyl alcohol or other denaturing material or materials, or admixtures of the same, suitable to the use for which the alcohol is withdrawn, but which destroys its character as a beverage and renders it unfit for liquid medicinal purposes; such denaturing to be done upon the application of any registered distillery in denaturing bonded

warehouses specially designated or set apart for denaturing purposes only, and under conditions prescribed by the Commissioner of Internal Revenue with the approval of the Secretary of the Treasury.

"The character and quantity of the said denaturing material and the conditions upon which said alcohol may be withdrawn free of tax, shall be prescribed by the Commissioner of Internal Revenue who shall, with the approval of the Secretary of the Treasury, make all necessary regulations for carrying into effect the provisions of this act.

"Distillers, manufacturers, dealers and all other persons furnishing, handling, or using alcohol withdrawn from bond under the provisions of this act, shall keep such books and records, execute such bonds and render such returns as the Commissioner of Internal Revenue, with the approval of the Secretary of the Treasury, may by regulation require. Such books and records shall be open at all times to the inspection of any internal-revenue officer or agent."

The National Prohibition Act recently passed had a double purpose as indicated by Congress in naming the Act after due deliberation as follows:

> "An Act to prohibit intoxicating beverages, and to regulate the manufacture, production, use, and sale of high-proof spirits for other than beverage purposes and to insure an ample supply of alcohol and promote its use in scientific research, and in the development of fuel, dye, and other lawful industries."

It will be noted that one of the purposes of the Act is *to insure an ample supply of alcohol and promote its use in the lawful industries.*

This Act provides that undenatured ethyl alcohol may be withdrawn free of tax by the following:

> "The United States or any Governmental Agency thereof, or by the several States and Territories or any municipal subdivision thereof, or by the District of Columbia, or for the use of any Scientific University or of College of Learning, any laboratory for use exclusively in scientific research, or for use in any Hospital or Sanatorium."

Notice should be taken that *any laboratory may obtain pure ethyl alcohol tax-free for use exclusively in scientific research.*

Alcohol may also be withdrawn tax-free for denaturation in accordance with regulations No. 61, which provide:

> "Upon the filing of application and bond and issuance of permit denaturing plants may be established upon the premises of any industrial alcohol plant, or elsewhere, and shall be used exclusively for the denaturation of alcohol by the admixture of such denaturing materials as shall render the alcohol or any compound in which it is authorized to be used unfit for use as an intoxicating beverage.
>
> "Alcohol lawfully denatured may, under regulations, be sold free of tax either for domestic use or for export."

Nearly fifty formulæ have been authorized which are exempt from tax when used for industrial purposes under U. S. Internal Revenue permit and bond. Five separate formulæ of completely denatured alcohol have been authorized, which alcohol may be used by manufacturers or the general public without permit or bond, and which alcohol is not subject to tax or regulation by the Internal Revenue Bureau.

MANUFACTURE OF ALCOHOL.

Raw Materials.

In the manufacture of alcohol for industrial purposes a great variety of raw materials may be used. Alcohol is made by the fermentation of sugars, but the only sugars which are directly fermentable into alcohol and carbon dioxide are the sugars having the composition $C_6H_{12}O_6$, or the monosaccharoses, such as dextrose and levulose. All other sugars, such as cane sugar $C_{12}H_{22}O_{11}$, or the disaccharoses, are not directly fermentable, but by action of certain enzymes (*e.g., invertase*) they are converted into fermentable sugars; and then an enzyme of the yeast (zymase) brings about alcoholic fermentation.

Alcohol may also be made from more complex compounds. Starch, dextrin, and cellulose are all highly complex substances, the molecules of which seem to consist of combinations of the molecules of the mono- or di-saccharoses, with loss of the elements of water; they are therefore called the poly-saccharoses.

These poly-saccharoses, when hydrolyzed, form fermentable sugars. Assuming the formula for starch, for example, as being $(C_6H_{10}O_5)n$ the reaction is as follows:

$$\underset{162}{(C_6H_{10}O_5)n} + \underset{18}{nH_2O} \longrightarrow \underset{180}{n(C_6H_{12}O_6)}$$

Thus, the starch will take up one-ninth of its weight of water, or nine pounds of starch will form 10 pounds of fermentable sugar.

$$\underset{180}{C_6H_{12}O_6} \longrightarrow \underset{88}{2CO_2} + \underset{92}{2C_2H_5OH}$$

$$\frac{180}{92} = \frac{10}{x} = 5.111$$

This reaction would give theoretically a little more than five pounds of absolute alcohol from 9 pounds of starch or 10 pounds of fermentable sugar, or a theoretical yield from starch of 56.78 per cent. alcohol by weight. In practice, when making alcohol for industrial purposes, where no attention is paid to flavor, etc., a yield of over 90 per cent. of the theoretical is obtained.

The raw materials which may be used for the production of industrial alcohol may be more or less arbitrarily classified as follows:

Grains and Kernels:

Wheat
Barley
Oats
Rye
Millet
Rice
Buckwheat
Corn
Maize
Ragi

Roots:

Sugar beets
Potatoes
Artichoke (Jerusalem)
Cassava
Sweet potatoes
Carrots
Turnips
Mangolds

Fruits and Berries:

Apple
Apricot
Banana
Orange
Grape
Peach
Plum
Pear
Cherries
Melons
Pineapple
Prickly pear
Watermelon
Figs
Raspberries
Huckleberries
Blackberries
Gooseberries
Currants
Prunes

Strawberries
Dates
Mulberries

Stems and Leaves:

Agave
Cactus
Sorghum
Stalks of sugar corn
Sugar cane
Zamia palm (*Macrozamia*)
Grasstree (*Xanthorræa*)
Nipa palm
Sotol
Seaweed
Date palm
Mahua (*Bassia Satifolia*)
Cocoanut palm
Sago palm
Other trees
Bracken and other vegetation

Trade Wastes

Corn cannery refuse
Sulphite liquor
Garbage
Sawdust
Cane molasses
Beet molasses
Fruit
Gases from coal carbonizing plants

In addition to the above may be mentioned peat, horse-chestnuts and acorns.

At various times, in the different countries, practically all grains have been used for the production of alcohol. The yields obtained differed widely, due to the method of handling, also to the particular grain and its composition. McIntosh ("Industrial Alcohol," p. 62) gives the average composition of grains and cereals as follows:

	Old wheat	Barley	Oats	Rye	Maize	Rice
Water	11.1	12.0	14.2	14.3	11.5	10.8
Starch	62.3	52.7	56.1	54.9	54.8	78.8
Fat	1.2	2.6	4.6	2.0	4.7	0.1
Cellulose	8.3	11.5	1.0	6.4	14.9	0.2
Gum and sugar	3.8	4.2	5.7	11.3	2.9	1.6
Albumenoids	10.9	13.2	16.0	8.8	8.9	7.2
Ash	1.6	2.8	2.2	1.8	1.6	0.9
Loss	0.8	1.0	0.2	0.5	0.7	0.4
Total	100.0	100.0	100.0	100.0	100.0	100.0

McIntosh ("Industrial Alcohol," p. 65) also says that the yield of alcohol from the grains is:

	Alcohol sp. gr. 0.9427. 9/11 British proof spirit, in lbs.
100 pounds wheat	40–45
100 pounds rye	36–42
100 pounds barley	40
100 pounds oats	36
100 pounds buckwheat	40
100 pounds maize	40

Wright states ("Distillation of Alcohol," p. 126) that the yields of alcohol from grains are:

220 pounds wheat	give 7.0	gallons pure alcohol.
220 pounds rye	give 6.16	gallons pure alcohol.
220 pounds barley	give 5.5	gallons pure alcohol.
220 pounds oats	give 4.8	gallons pure alcohol.
220 pounds buckwheat	give 5.5	gallons pure alcohol.
220 pounds corn (Indian)	give 5.5	gallons pure alcohol.
220 pounds rice	give 7.7	gallons pure alcohol.

Corn has been used in nearly all countries for the production of alcohol. The average corn should give theoretically 20.7 pounds of absolute alcohol per bushel. The yield actually obtained is about 16 to 18 pounds per bushel. On account of the high price of the corn suitable for food purposes, only the lower grades of this material are used.

Maize has been a very important source of alcohol in this country for many years. Dry corn of good quality should contain at least 65 per cent. of sugars and starch, and should yield from 98 to 105 gallons of 180° proof alcohol per ton of shelled kernels.

Sugar Beets.—The average sugar content of the varieties of beets used for alcohol production varies between 12 and 20 per cent. Beets have not been used directly to any extent for alcohol production in this country. In France they have been used to a considerable extent. The data obtained from distillery yields in France show that, from every 220 pounds of sugar contained in the beets entering the distilleries, 15.64 gallons of alcohol of 100 per cent. strength were produced, equivalent to 17.4 gallons at 180° proof.

Beet Molasses.—A refuse from the manufacture of beet sugar is used in large quantities abroad as a raw material for the production of alcohol. It usually contains nearly 50 per cent. sucrose, with only traces of reducing sugars, and generally needs only to be diluted to prepare it for fermentation. One ton should yield between 75 and 80 gallons of alcohol of 180° proof.

Potatoes.—In the European countries potatoes have been used very extensively for the production of industrial alcohol. Most of the industrial alcohol made in Germany is derived from a potato grown chiefly for this purpose. In Germany the yield of alcohol is about 26 gallons absolute alcohol per ton of potatoes. This yield is approximately 80 per cent. of the theoretical, based on the starch content of the potatoes. With an average starch

content of 18 per cent. they should yield about 30 gallons per ton. In some localities sweet potatoes have been used very successfully for the production of alcohol, but not to such an extent as the potato which is grown in Germany for use in the manufacture of alcohol.

The sweet potatoes used for alcohol manufacture contain a considerably larger amount of fermentable matter than the common potato, much of it in the form of sugar; but on account of their irregular form and the difficulty of removing the culls except by hand labor, they would probably be a more expensive material. With a content of 28.8 per cent. fermentable substances, a ton should produce about 38 gallons of alcohol.

Artichoke.—The tubers of the artichoke contain, on an average, about 14 per cent. of directly fermentable levulose and about 2 per cent. of starch which can be converted into sugar.

Sorghum.—This plant contains from 6 to 15 per cent. of levulose and crystallizable sugar. It may become a source of industrial alcohol.

Sorghum deserves considerable attention because of the readiness with which it is grown, the extent of the territory in which it flourishes, and the large amount of sugar which certain varieties contain.

Fruits and Fruit Wastes.—Fruits and fruit wastes may be used for the production of alcohol, but in most cases the fruits are too valuable to use for such purposes, and the wastes do not occur in sufficient quantities to be available at a distillery. Transportation of these wastes is of course not feasible. The possible yields of alcohol from the various kinds of fruits are given by Wiley (U. S. Department of Agriculture, Bureau of Chemistry Bulletin No. 130 (1910), page 29):

Kind of fruit	Average percentage of total sugars, calculated as dextrose	Gallons of 180° alcohol yielded by total sugars contained in one ton of material
Apple	12.2	18.3
Banana	13.8	20.7
Grape	15.0	22.6
Orange	5.4	8.1
Peach	7.6	11.4
Pear	10.0	15.0
Pineapple	11.7	17.6
Prickly pear	4.2	6.3
Tomato	2.0	3.0
Watermelon	2.5	3.7

While many different *berries* have been used in the making of alcoholic beverages, in most cases they cannot be used economically for the production of industrial alcohol.

Another author (*Scientific Australian*, 1918, p. 968) states that the approximate yield of alcohol obtainable from various sources is:

Material	Imperial gallons of alcohol (95 per cent.) per ton of 2,240 lbs.
Sugar molasses	65
Sorghum stalks	12–½
Wheat	83
Barley	70
Maize	85
Sorghum grains	87
Potatoes	20
Sweet potatoes	35
Sugar beet	18
Artichokes	22
Cassava	39
Apples and pears	12
Apricots and peaches	11
Grapes	18
Bananas	13
Watermelons	3
Zamia palm (*Macrozamia*)	18
Grasstree (*Xanthorræa*)	12
Sawdust (soft woods)	20

The *agave and cactus* have been used in Mexico and in the southwestern parts of the United States for the production of alcoholic beverages. It is possible that they may be used for the production of industrial alcohol, but as yet they are not so used commercially.

Stalks of Sugar Corn.—Stalks of sugar corn contain considerable amounts of sucrose and of reducing sugars, making this material valuable as a source of alcohol.

Sugar Cane.—Sugar cane under ordinary circumstances is too valuable to be used for industrial alcohol production, but at times, as when the cane has been heavily frosted, it may be used. The yield of alcohol from sugar cane averages between 15 and 20 gallons of alcohol 180° proof per ton of cane.

Nipa Palm.—Concerning the nipa palm as a raw material for industrial alcohol, the following statement has been made ("Pure Products," 1918, No. 14, p. 286): "There are over 100,000 acres of nipa swamp now available in the Archipelago

(Philippines) of which about 90 per cent have never been touched, and it is estimated that the untapped swamp area of the island would yield 50 million gallons of alcohol every season."

The most important raw materials for the production of industrial alcohol are the various trade wastes.

Corn Cannery Waste.—Corn cannery waste has been used to some extent in this country as a raw material for alcohol production. These wastes amount to about 40 per cent. of the total weight of corn brought to the factory, not counting the husks as available, although these amount to nearly one-third of the total weight of the corn. It is possible to obtain 10 to 11 gallons of 180° proof alcohol per ton of corn hauled to the factory, or about 27 gallons per ton of factory waste excluding husks.

Sulphite Liquors.—Fermentable sugars are found in small percentages in the waste liquors resulting from sulphite paper pulp manufacturing. A large number of processes have been tried and patented for the production of alcohol from sulphite waste. Although there are many attractive features to the manufacture of alcohol from sulphite liquor, there are many technical difficulties to be overcome. Even though these difficulties may be overcome, this source of alcohol will not be very great because there are very few localities where a sufficient amount of waste sulphite liquor could be collected to produce over 1500 to 2000 gallons per day. The overhead expense of operating plants with such small outputs is high, and the total amount produced would not be a factor in the market.

Sawdust.—A number of patents have been issued to various inventors to cover processes for the production of alcohol from sawdust. These patents cover the conditions of temperature and pressure of the hydrolysis, and the use of various acids which have been proposed to catalyze the reaction. In the Classen process, which was tried out at Chicago several years ago, the sawdust was cooked under pressure with live steam in the presence of sulphur dioxide as the hydrolyzing agent. This enterprise failed on account of poor yields. The Standard Alcohol Company built a plant at Fullerton, La., to operate under the Tomlinson patents; in this process either sulphuric acid or a mixture of sulphuric and sulphurous acids was used as a hydrolyzer. A later plant was built at Georgetown, South

Carolina, using the same process. F. W. Kressmann ("The Congressional Record," 1916) stated that the Forest Products Laboratory results indicated that the possible yield would be approximately 20 gallons of alcohol per ton of dry sawdust and that the cost would be:

Yeast nutrients: This item may go as high as $0.035 in some sections since the war; also rapidly advancing prices of iron, steel, and copper, particularly the latter, will require some increase in the estimate, which were figures for market conditions existing over a year ago	$0.015–$0.020
Repairs and materials (exclusive of fuel and wood)	.030– .040
Labor	.015– .030
Wood and fuel	.020– .020
Interest at 7 per cent.	.019– .020
Depreciation at 10 per cent.	.023– .035
Overhead, taxes, etc.	.015– .030
Total	$0.137–0.195

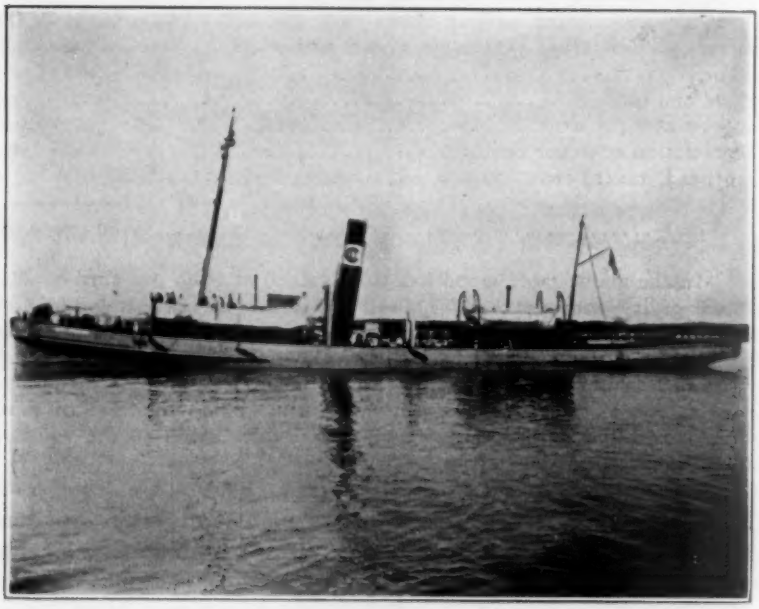
"In the above table wood has been valued at $0.40 per cord of 1800 pounds of dry wood per cord. This should consist of sawdust and hogged refuse, but should not contain over 10 per cent. of bark, since the yield of sugars and alcohol from bark is very low. A large quantity of bark would mean running a large volume of inert material through the alcohol plant at considerable expense without return, and in the case of most barks would add large quantities of undesirable tannin to the solution to be fermented."

At the present time there are two plants of relatively small capacity in operation in the United States, manufacuring alcohol from sawdust, one at Georgetown, South Carolina, and the other at Fullerton, Louisiana.

Cane Molasses.—The chief source of industrial alcohol in the United States is cane, or black strap, molasses. Only a few years ago the disposal of molasses by the sugar mills was a serious trade waste problem, but it is now very largely used the world over as a raw material for alcohol manufacturing. In the East and West Indies molasses disposal was a matter of expense. The conversion of molasses into alcoholic liquor, especially into rum, is an old enterprise. West India rum has been famous in New England for more than 200 years. But the use of molasses in large quantities for industrial alcohol production is a development of the last few years. As far as ease of manipulation is

concerned, molasses unquestionably surpasses any other known material. Also in the past it has been a very cheap material. Ordinarily it contains both sucrose and reducing sugars in varying proportions. The grades used by distillers usually contain between 45 and 60 per cent. sugars, averaging about 50 per cent. The yield of alcohol from such molasses is from 0.6 to 0.85 proof gallons of alcohol per gallon of molasses. A large portion of the

FIG. 1.



Molasses lighter, Cuba.

world's molasses is still a waste product due to the difficulty and expense of transportation to the commercial centres.

Molasses from Cuba and Porto Rico is of special importance to the United States, since several million tons are available annually for the production of alcohol. Many of the producing mills are located on waterways. From these mills the molasses is collected in light draught tank barges or lighters and transported to deep-water shipping points. From the other mills the molasses is taken in hundreds of tank cars and, in a few instances, in barrels or hogsheads. Large storage tanks are pro-

vided at the deep-water shipping ports for containing the molasses until sufficient quantity has accumulated to load a tank steamer. Tank steamers, such as are used for the transportation of petroleum, are used to carry the molasses from these storage points to various plants in the United States: in Boston, Brooklyn, Baltimore, New Orleans and other points.

Calcium Carbide.—Another source of alcohol which may

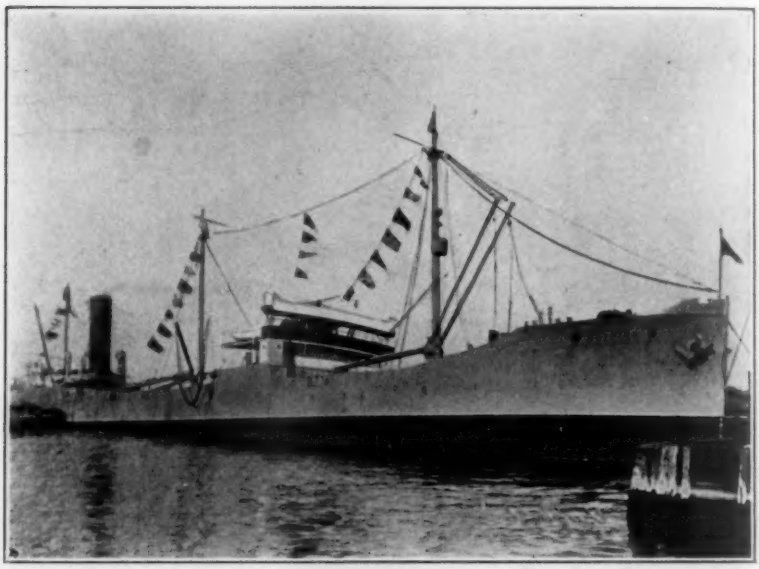
FIG. 2.

Molasses cars, Cuba.

become important in localities where cheap power is available is calcium carbide. It was stated by Consul W. P. Kent, of Berne, Switzerland ("Commerce Reports," 1917, No. 102, p. 426), that installations were started with about 20,000 horse-power minimum and 30,000 horse-power maximum (summer time), which would produce from 7500 to 10,000 tons of alcohol per annum. Calcium carbide is produced by the usual electric furnace method, and acetylene from the calcium carbide by the action of water. Two methods are used in the production of alcohol from the acetylene. (1) The acetylene is hydrogenated by catalytic means

and ethylene is produced. The ethylene is dissolved in sulphuric acid; and alcohol and sulphuric acid are formed upon saponification. (2) Acetaldehyde is produced catalytically from the acetylene. The acetaldehyde is oxidized to acetic acid or reduced to alcohol by means of catalyzers. Great care is used in the selection of a catalyzer in order to eliminate numerous complicated side reactions which are liable to occur.

FIG. 3.



Molasses tanker.

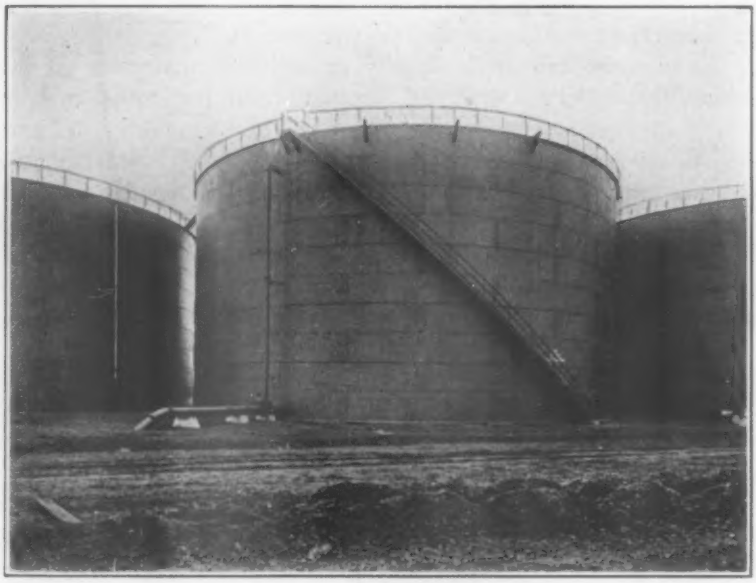
Ethylene.—Recently a committee made a report to the British Parliament on "Various Matters Concerning the Production and Utilization of Alcohol for Power and Traction Purposes." This report emphasized the possibility of converting the ethylene obtained from coal- and coke-oven gases into alcohol. H. F. Grady, London Attaché of the Bureau of Foreign and Domestic Commerce ("Commerce Reports," No. 219, p. 1460 (1919)), in discussing this proposition, states in part:

> The amount of ethylene in the gas works and coke-oven gases of Great Britain is estimated to be sufficient to yield annually up to 150,000,000 gallons of 90 per cent. alcohol, which the *Times* declares the manufacturer could afford to sell for 15.3d (30 cents) a gallon.

Mr. Grady ("Commerce Reports," No. 21, p. 506 (1920)) in discussing the development of this process states:

The extraction of alcohol from coke-oven gas on a commercial scale was proved to be possible at a meeting of the Cleveland Institution of Engineers at Middlesbrough (England) by Mr. E. Bury, of the Skinningrove Iron and Steel Works. Mr. Bury showed that he had succeeded in extracting ethyl alcohol and its derivatives. The practical working of Mr. Bury's process at the Skinningrove plant, where 5800 tons of coal are carbonized per week, revealed an average yield of 1.6 gallons of alcohol per ton of coal carbonized.

FIG. 4.



Molasses storage, United States; capacity of each tank, 1,500,000 to 2,000,000 gallons.

Straw.—Recently Henry Ford (*Oil and Gas Journal*, 18, 36) has been quoted as follows:

I am now making the best fuel my tractors can use out of straw. I have got an inexhaustible supply of fuel on my farm and believe the day is coming when we will extract the alcohol out of fruit for fuel and use the rest for food. I am putting up a $35,000 plant now to manufacture alcohol from straw alone; just to show people that it can be done.

This process is still of an experimental nature and has no commercial significance at present.

Preparation of Raw Materials.

As the saccharine raw materials contain their fermentable matter in the form of diffusible sugars which are already in solution, they require relatively little preliminary treatment to fit them for fermentation. Materials like sugar beets and fruits are best prepared by rasping or grinding and pressing. Fibrous materials, like sorghum and cane, may be pressed in roller mills or they may be sliced and extracted in diffusion batteries. Sugar beets can also be extracted by diffusion.

Beet molasses, cane molasses, and other saccharine materials when in liquid form, are diluted with water, and acidified, and are then ready for the alcoholic fermentation.

As already indicated, starchy or cellulose materials do not themselves undergo alcoholic fermentation, but must first be converted into a fermentable sugar. "Mashing" is the term used to designate the series of processes by which starchy raw materials are prepared for yeast production or fermentation by means of heat and of enzyme action. The starchy material is first ground and heated with water to gelatinize the starch. This forms the "mash" which is then saccharified by means of malt (some grain, usually barley, in which the production of the enzyme diastase has taken place), the conversion of starch into sugar being effected through the action of the enzyme diastase (amylase). The resulting liquid is known as the "wort" and is essentially a solution of sugar with dextrin and other components obtained from the starchy material.

These processes of mashing and saccharification result in the formation of soluble and fermentable sugar, and incidentally in the development of certain nitrogeneous substances which are necessary to yeast activity.

Fermentation.

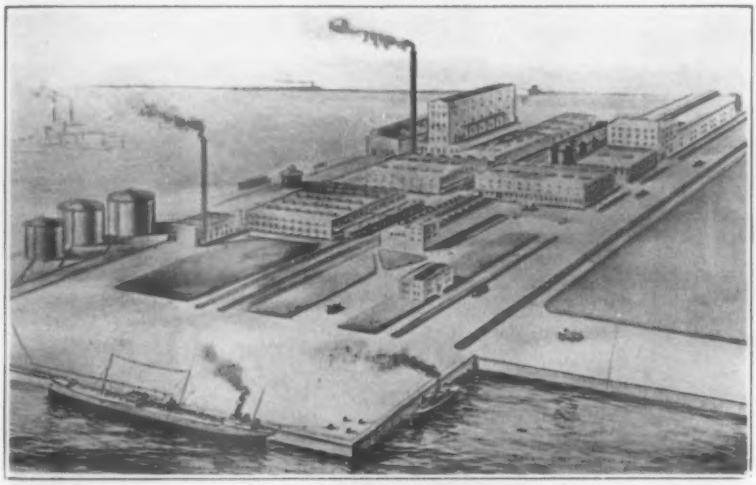
After the material has been prepared ready for fermentation it is brought to a proper temperature and the yeast added. The yeast which is a vegetable mono-cellular organism, under the conditions prevailing in distillery practice, reproduces itself by budding and sprouting. Yeast reproduces very rapidly and most distilleries start with biologically pure cultures and develop them until a sufficient number have been grown to start fermentation in the large fermenters. There are usually several

stages to the growth of sufficient yeast and several changes to larger containers as the growth takes place.

After the addition of yeast to the liquid to be fermented for alcohol, fermentation proceeds and the alcoholic mixture or "mash" is produced. The alcohol is obtained from the mash by distillation and rectification.

It has been found that certain moulds secrete the amylase (diastase) and also fermentation enzymes. This property has been utilized in a process which combines saccharification and

FIG. 5.



Modern industrial alcohol plant.

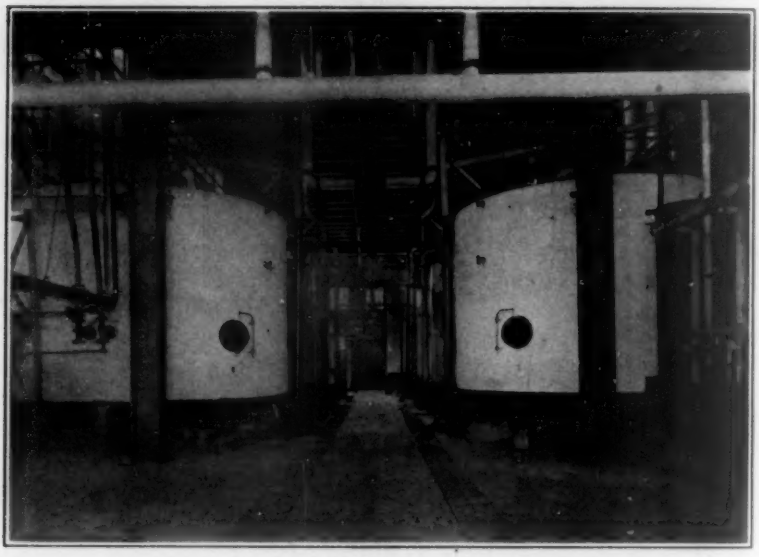
fermentation, whereby the use of malt is dispensed with in obtaining alcohol from starchy materials. This method has been employed on a large scale in Belgium, France, Hungary, Spain, Italy, and Germany. This so-called "Amylo" process originally employed the mucor *Amylomyces Rouxii* from which the process was named. This organism was later on supplanted by other moulds. This process has many other advantages over the older process and its development has been very rapid and far-reaching in its effect.

Distillation.

Theoretically the alcoholic fermentation of sugars should give carbon dioxide and ethyl alcohol, but the decomposition is

not as smooth a process as this, for there are always formed a number of by-products which decrease the amount of alcohol recovered. Yeast is an organism which consumes sugar for its nourishment and propagation, and also converts sugar into other substances besides alcohol and carbon dioxide during its metabolic changes, thus reducing the percentage conversion. The products other than alcohol formed in the fermentation are usually glycerol, succinic acid, lactic acid, butyric acid, acetic acid, pro-

FIG. 6.



Alcohol stills, capacity, 60,000 gallons each.

pionic acid, formic acid, aldehydes, higher alcohols, and ketones, with sometimes small quantities of various esters (ethyl acetate, butyrate, caproate, etc.). In order to separate the alcohol from these products as well as the yeast cells, water, etc., a distillation is made.

Upon completion of the fermentation, the fermented liquors are transferred to a still in order that the alcohol may be removed from the mass. In the United States the development of the stills used for this purpose has been very interesting. The early settlers along the eastern coast, when they started to make their alcohol, had to rely on the use of a copper kettle still which

was boiled over an open fire; and the resulting vapors were condensed in a cooled coil. When the charge was distilled out, the kettle was cleaned, and the distillate obtained was charged into the still and redistilled. This process of redistillation was repeated until alcohol of the desired strength was obtained. The next improvement was the introduction of a steam boiler and the heating of the still by means of steam. It was found that

FIG. 7.

Tail boxes flowing 60,000 gallons of pure alcohol per day.

even a number of distillations would not give an alcohol of suitable strength, so the idea was conceived to return to the still all but the desirable fraction. This resulted in the still with a simple dephlegmator which allowed the condensed liquid to return to the still. In time this was modified so that a dephlegmating column was introduced. At present there are innumerable schemes to enable better separation of the components, a number of them designed in such a way that they may be run continuously.

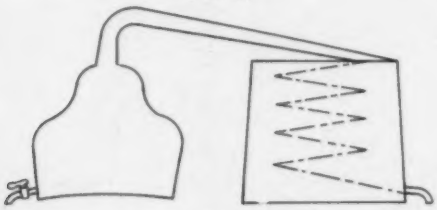
Usually the alcohol is separated from the fermented mass by a primary distillation. This distillation separates the alco-

holic liquors from the yeast, water and most of the other impurities of the fermentation. This alcohol still contains too high a percentage of aldehydes, water and higher boiling components (fusel oil) to be used commercially; so it then undergoes a secondary separation or rectification.

Rectification.

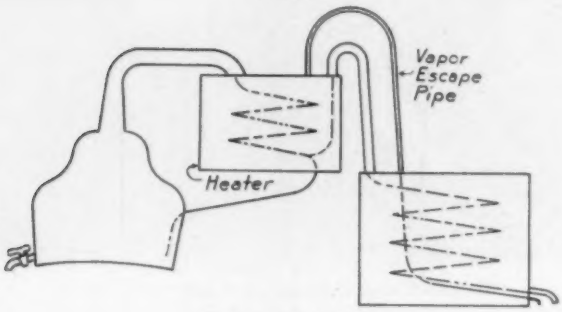
The purpose of this fractional distillation is to cause a separation of the alcohol from the water, aldehyde, and fusel oil

FIG. 8.



Simplest form of pot still.

FIG. 9.

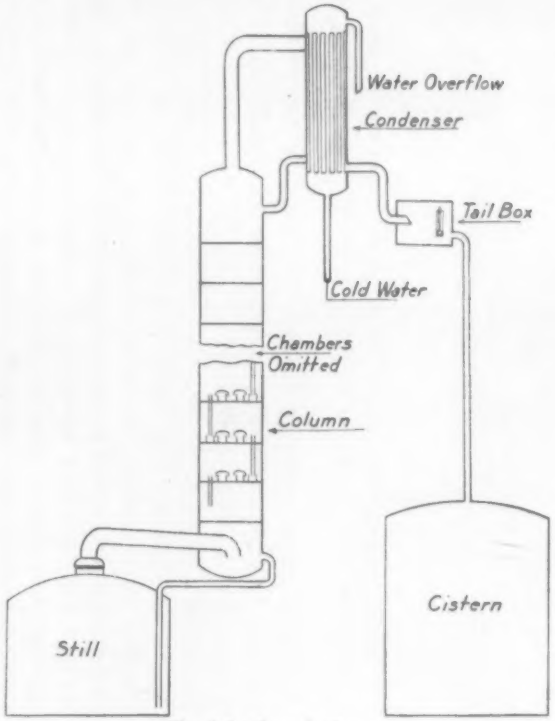


Pot still with heater.

with which it is associated when obtained by the first distillation.

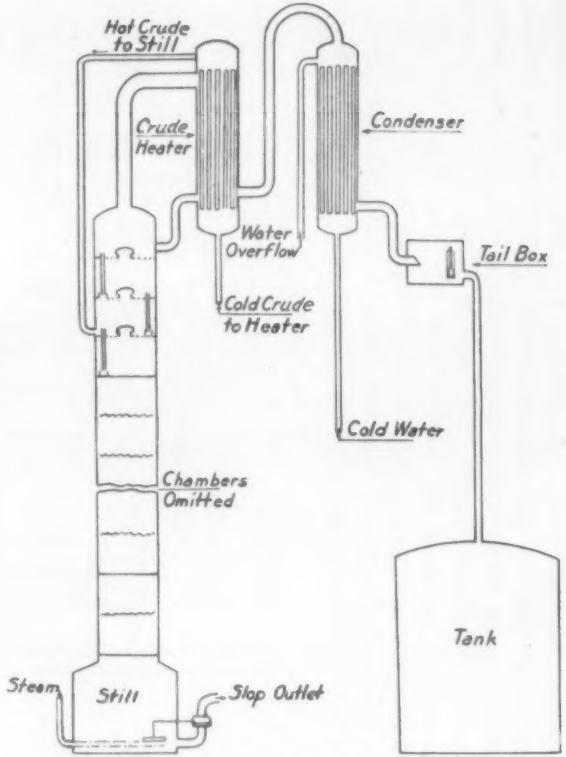
The apparatus used for this purpose usually consists of a kettle still which is connected to the bottom of the rectifying column. This column consists of a vertical cylindrical shell, which is divided horizontally into a number of sections by plate partitions. These plates are constructed so that a volume of liquid is held at a certain level before it is allowed to overflow to a next plate below. The ascending vapors are made to bubble through the liquid held on the plates. Thus the column is a series of

FIG. 10.



Simple kettle and column.

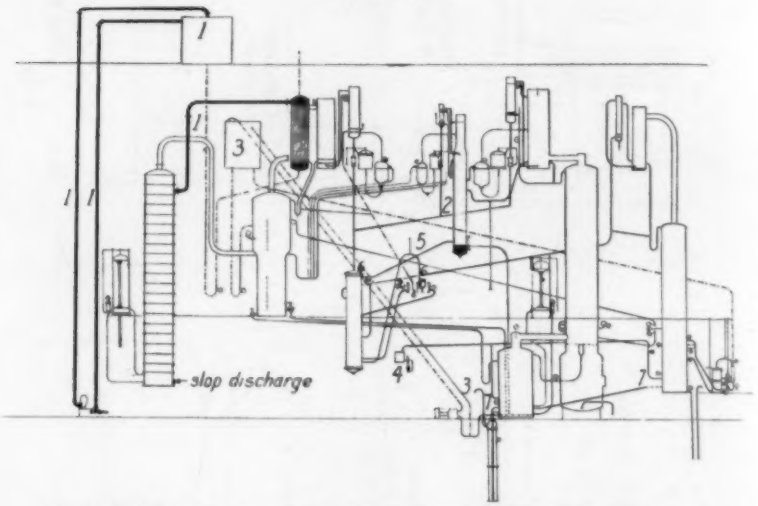
FIG. 11.



Simple crude alcohol still.

small stills, each plate having a little lower boiling fraction than the next plate below it. The continued washing of the ascending vapors by the liquid condensed on the plates, and the bubbling of the vapors through the liquid, causes a very complete separation of the components. On the top of the column the usual practice is to pass the vapors from the top plate through a dephlegmator which causes the final separation. The run back from the dephlegmator is either placed in the top of the column or between two of the top plates. The vapors from the top of the

FIG. 12.



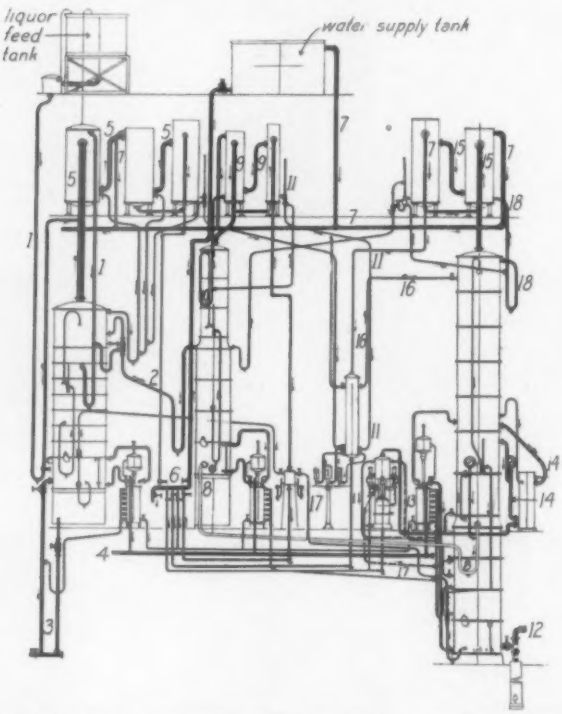
GUILLAUME SYSTEM DIRECT DISTILLATION AND RECTIFICATION.
1, Crude alcholic liquor; 2, aldehydes; 3, warm water; 4, fusel oil; 5, cold water; 6, alcohol; 7, steam.

dephlegmator are passed through a condenser where they are liquified. By means of such an apparatus it is possible to hold the composition of the alcohol out from the condenser to 188 to 194° proof, or 94 to 97 per cent. alcohol.

As the uses for the higher grades of alcohol developed, the demand caused more careful attention to be paid to the details of rectification. In France and Germany the progress in this respect was especially marked. Continuous methods of distillation and rectification were worked out, such as the Barbet and the Guillaume rectification systems. That these must be complex can be realized when we consider that the object is to separate alcohol

from the several component mixture composed of water, aldehydes, higher alcohols or fusel oil, acids and fermentation impurities. Alcohol forms mixtures with water which distill at a constant temperature when the pressure is kept constant, without

FIG. 13.



BARBET SYSTEM CONTINUOUS DISTILLATION AND RECTIFICATION.

1, Crude alcoholic liquor; 2, high wine, crude; 3, slop from distilling column; 4, steam piping; 5, alcohol vapor, distilling column; 6, water supply piping; 7, hot water piping; 8, high wines purified; 9, alcoholic vapor, heads concentrating column; 10, condensed alcoholic liquid from dephlegmator heads concentrating column; 11, condensed head products; 12, slop from rectifying and exhausting column; 13, fusel oil removal pipes, rectifying and exhausting column; 14, liquid connecting pipes to special cooler; 15, alcoholic vapor, rectifying and exhausting column; 16, refined alcohol; 17, head products from rectifying and exhausting column; 18, condensed alcoholic liquid from dephlegmator, rectifying and exhausting column.

change of composition. At 760 mm. pressure the mixture of constant boiling-point distills at 78.15° C. and contains 4.43 per cent. of water by weight (Young, *Trans. Chem. Soc.*, **81**, 710 (1902)). Since this temperature is lower than the boiling-point of either of the two components, it is impossible to obtain a pure

FIG. 14.

Modern bonded alcohol warehouse.

FIG. 15.

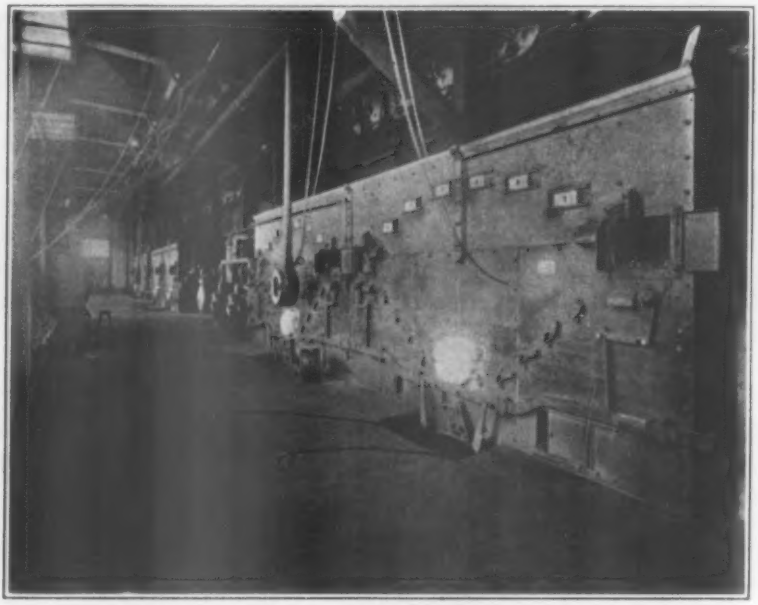
Present type of denaturing warehouse.

alcohol from a dilute aqueous solution by fractional distillation only.

The illustrations show better than words the development of distillation and rectification, and they also indicate the complexity and elaborateness of the present-day type of apparatus.

In the United States there are a large number of rules and regulations determining the details of control and operation of

FIG. 16.



Boiler house of alcohol plant containing ten 600 H. P. boilers.

an alcohol distillery. In the larger industrial distilleries these rules oftentimes constitute an item of considerable expense. When they were made most of them had particular reference to the small distilleries having a capacity of but a few gallons of alcohol and they are burdensome in the large distilleries having a capacity of several million proof gallons per year.

PRODUCTION AND DISTRIBUTION.

In this country the production and distribution of industrial alcohol is so regulated that the cost of the alcohol to the consumers is materially increased.

The rules and regulations which have been recently released by the U. S. Internal Revenue Bureau, have removed to a great extent the antiquated regulations by which the industry has been hampered until the present year. These restrictions were an outgrowth of the old attempts to prevent the production of "illicit" whiskey, and it is gratifying to know that the Government has at last realized that these rules had no place in governing the procedure of the large industrial distillers of to-day.

The manufacturers and users, however, who, because of their product or processes, must use pure ethyl alcohol, are still greatly hampered because they must obtain their alcohol through the organization and under the same regulations that govern the sale, distribution, and use of whiskey. It is to be hoped that the Government may relieve the manufacturers of lawful goods unfit for beverage purposes of some of this "red tape" and the attendant taxes.

In considering the production of alcohol, it is interesting to notice the production of some of the foreign countries, and also to compare the production in some of them with that of the United States.

Germany.

Germany has been one of the largest producers and users of industrial alcohol. Because of war conditions, only statistics up to the year 1914 are available. The following table indicates the use of *tax-free* alcohol in 1911 and 1912:

TABLE I.

Consumption of Tax-free Alcohol in Germany.

Kinds of tax-free alcohol	United States gallons of pure alcohol	
	1911	1912
Completely denatured:		
With general denaturing formula	25,907,033	30,975,120
With benzol mixture	1,154,604	1,224,775
Incompletely denatured:		
With 5 liters wood alcohol	503,105	422,426
With 0.5 liter turpentine	27,667	36,642
With other denaturants	8,798,962	8,115,043
Without denaturation:		
For hospitals and similar institutions	137,702	144,170
For public scientific institutions	50,635	54,146
For military technical institutions	287,866	266,093
For gunpowder and fulminate factories	278,309	316,932
Total	37,145,883	41,549,348

The above table gives only the figures for tax-free alcohol and does not take into account the alcohol used for industrial purposes upon which a tax may have been paid.

The above undenatured alcohol was pure ethyl alcohol, sold and used under Government supervision.

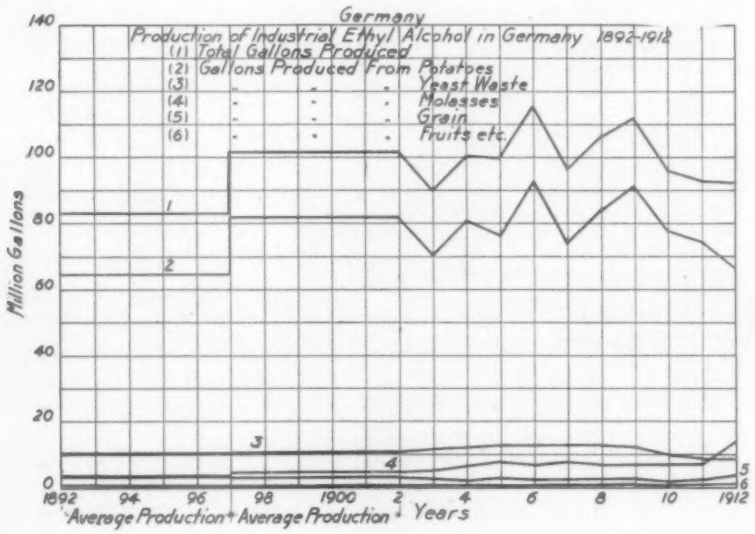
The total production of alcohol from the various raw materials is indicated in Table II.

TABLE II.

Production of Alcohol in Germany.

Years	Potatoes distilleries, U. S. gals.	Yeast distilleries, U. S. gals.	Grain distilleries, U. S. gals.	Molasses distilleries, U. S. gals.	Fruit and other distilleries
1887/88–1891/92	59,826,000	10,190,000	3,065,000	3,330,000	686,000
1892/93–1896/97	63,362,000	10,370,000	3,615,000	3,620,000	898,000
1897/98–1901/02	81,730,000	10,900,000	4,750,000	3,190,000	872,000
1902/03	70,000,000	11,500,000	4,990,000	2,350,000	502,000
1903/04	80,420,000	12,060,000	6,204,000	4,410,000	608,000
1904/05	75,900,000	12,720,000	7,500,000	285,000	976,000
1905/06	92,820,000	12,670,000	7,000,000	219,000	819,000
1906/07	73,620,000	12,540,000	7,240,000	235,000	792,000
1907/08	83,100,000	12,770,000	6,440,000	272,000	1,005,000
1908/09	90,220,000	11,900,000	6,310,000	229,000	1,267,000
1909/10	77,600,000	9,460,000	6,150,000	1,936,000	1,005,000
1910/11	74,100,000	8,130,000	6,230,000	2,360,000	739,000
1911/12	66,000,000	7,925,000	13,100,000	3,380,000	898,000

CHART I.



Crampton, in his report on alcohol ("Production and Use of Denatured Alcohol"—Department of Commerce Publication—Special Agents' Series, No. 77), illustrates clearly the uses and consumption of *incompletely denatured alcohol* for two years which are typical of the pre-war period (Table III).

TABLE III.

Consumption of Incompletely Denatured Alcohol in Germany.

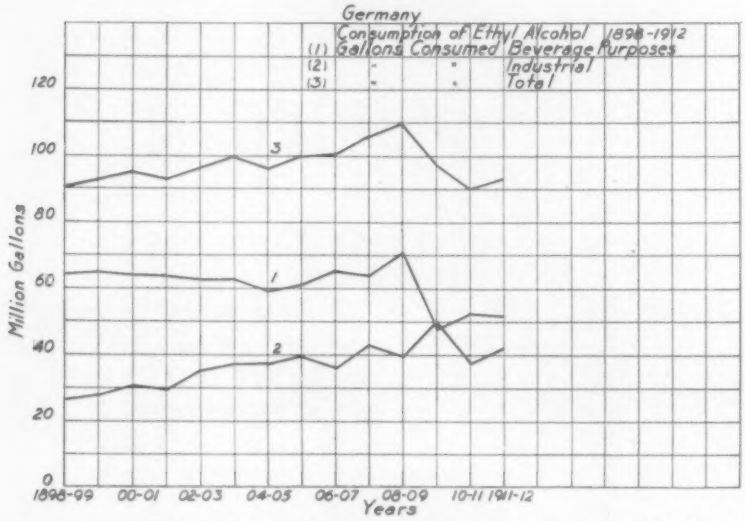
Industrial uses	United States gallons of pure alcohol	
	1911	1912
Manufacture of vinegar	3,958,574	3,953,928
Manufacture of vinegar for industrial purposes and for manufacture of acetates	160,961	86,777
Brewers' glaze	28,301	34,798
Finishing of rubber goods	2,323	2,165
Celluloid and pegamoid	1,396,111	1,105,975
Synthetic camphor	6,283	10,111
Sulphuric ether	916,766	859,162
Sensitive films, paper, and plates for photographic purposes	36,986	55,651
Electrode plates for electrical accumulators	1,214	26
Acetic ether	8,131	15,074
Adhesive preparations	1,373	554
Coal-tar colors, including by-products	208,058	219,991
Solutions of coal-tar colors, for dye printing	14,045	8,897
Material for ligatures	19,229	19,219
Other substances enumerated under d, section 4, of the regulations	788,093	649,757
Chloroform	2,825	5,861
Iodoform	5,623	5,491
Ethyl bromide and bromoform	1,162	1,822
Iodine or bromine containing fats for medicinal uses	2,350	2,270
Lac dyes	192,166	109,903
Stamping colors and inks	.....	.....
Brewers' pitch	106	106
Feeding of gas lamps	3,643	1,399
Finishing of silk ribbons	14,034	2,086
Cleaning of jewelry and fine metal ware	2,429	1,109
Lacquers of all kinds (exclusive of brewers' glaze and lac dyes)	904,068	840,365
Scientific preparations for teaching purposes	2,297	2,376
Solid soaps	76,586	70,224
Wool fats and oils	19,272	20,143
Other purposes	31,933	28,802
Total	8,804,942	8,114,042

As the *incompletely* denatured alcohol is used under Government supervision, it is possible to obtain the above data as to uses. The above, however, represents but a small part of the

denatured alcohol, and the data for the completely denatured alcohol is not available.

Germany, more than any other nation, makes extensive use of the privilege of tax-free alcohol. This is probably due, in part,

CHART II.



to her remarkable industrial expansion in recent years. Undoubtedly this expansion and production of alcohol was of great value and advantage to Germany in the recent war.

France.

In France the production and use of alcohol for industrial purposes has increased to a very marked degree. Statistics on the consumption of alcohol for industrial purposes have been published by Dachemin (*Bull. Soc. d'encour. Ind. Nationale*, vol 125) and are given in Table IV. Data on the consumption of tax-free alcohol during six years (1908–1913) have been included in a report by M. L. Calvert of the Paris Laboratory of the Ministere des Finances, and are presented in Table V.

United Kingdom.

In Table VI are given the figures for the consumption of methylated spirits in the United Kingdom during the five years ended March 31, 1913. This industrial methylated spirit is de-

TABLE IV.

Consumption of Alcohol for Industrial Purposes in France.

	1895 U. S. gallons	1900 U. S. gallons	1905 U. S. gallons	1910 U. S. gallons	1911 U. S. gallons	1912 U. S. gallons	1913 U. S. gallons
Heating and lighting	1,865,000	3,330,000	8,320,000	11,970,000	3,260,000	12,650,000	13,500,000
Varnishes	312,500	389,500	364,500	369,000	385,000	421,500	435,000
Cabinet furnishings	24,700	72,600	46,400	35,300	23,700	17,420	26,800
Plaster materials:							
Celluloid, etc.	58,000	190,000	562,000	504,000	494,000	489,000	472,500
Hat manufacture, etc.	14,160	10,900	6,020	17,900	15,770	18,050	26,650
Dyes and colors	4,860	4,120	14,600	21,400	21,600	20,400	22,600
Liquid rennet	2,975	3,245	3,910	4,645	4,570	4,960	5,170
Collodion	3,725	4,910	11,000	166,700	101,700	58,500	22,850
Chloroform	6,310	1,372	4,920	13,590	7,150	17,550	13,950
Chloral	4,410	8,130	10,080	5,175	1,820	2,320	2,340
Tannins	3,935	13,080	14,950	76	76	.....	.....
Various products:							
Chemicals and pharmaceuticals such as ether alkaloidal extracts, insecticides, transparent soap, etc.	14,250	101,800	178,600	95,000	86,900	113,300	124,400
Scientific uses	8,640	10,100	31,500	9,190	8,080	7,080	8,760
Fulminates, ethers, and explosives	1,223,000	1,712,000	2,957,000	3,620,000	3,390,000	4,111,000	4,460,000

TABLE V.

Consumption of Tax-free Alcohol in France.

Uses	United States gallons of pure alcohol					
	1908	1909	1910	1911	1912	1913
Heating and lighting	11,791,798	12,557,752	11,996,978	13,274,501	12,654,312	13,571,683
Varnishes	346,368	350,064	369,811	384,938	421,450	436,932
Thinning purposes	25,502	31,310	35,323	21,226	17,424	26,924
Plastic materials (celluloid fibrolithoid)	304,154	384,674	504,108	492,730	489,113	474,482
Hat making	14,546	15,391	17,926	1,531	18,058	26,738
Dyes and colors	12,645	19,219	21,226	21,330	20,407	22,604
Liquid rennet	4,224	4,752	4,646	4,620	4,963	5,194
Collodion	20,275	32,551	30,545	35,772	47,731	22,869
Artificial silk	306,372	340,164	177,382	101,297	58,582	7,764
Chloroform	5,914	5,095	13,596	7,154	17,556	14,018
Chloral	3,960	4,303	5,174	1,822	2,323	2,332
Tannins	766	53	792	792	.....	.....
Various products:						
Alkaloids, extracts, insecticides, transparent soaps, etc.	63,994	73,920	93,984	76,882	113,441	124,927
Scientific uses	9,715	8,210	11,827	8,078	7,075	8,798
Ethers, fulminate of mercury, explosives, etc.	3,134,050	3,459,588	3,613,632	3,393,139	4,110,850	4,447,309
Total	16,044,283	17,287,046	16,896,950	17,825,812	17,983,285	19,192,574

CHART III.

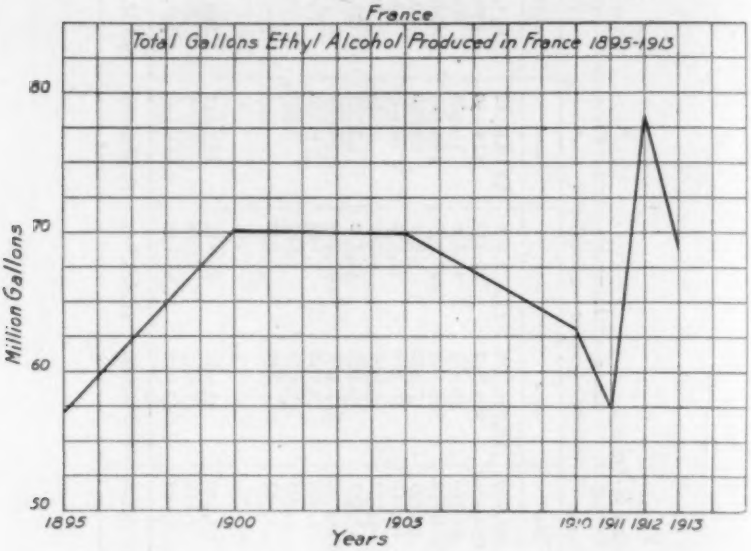


CHART IV.

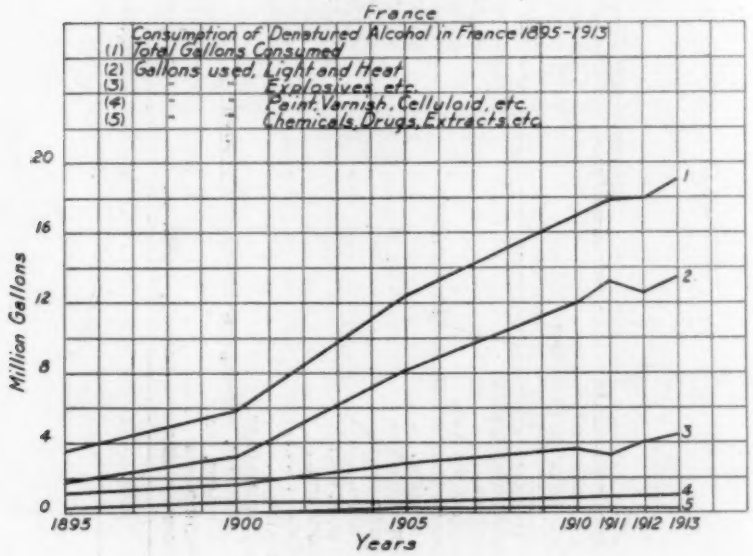


CHART V.

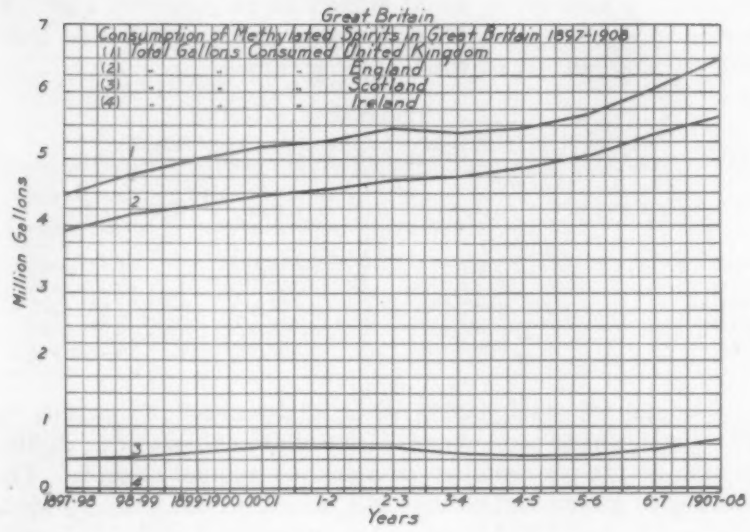
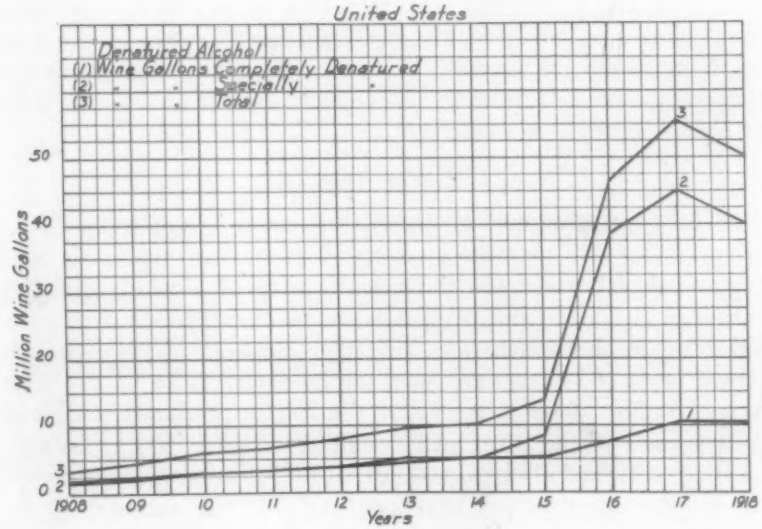


CHART VI.



natured by adding to 95 volumes of alcohol (90 to 95 per cent. strength) 5 volumes of wood alcohol of an approved type. It is used in the manufactures under bond and is not allowed to be sold or used outside of the bonded premises.

TABLE VI.

Consumption of Methylated Spirits in the United Kingdom.

Year ended March 31	Industrial imperial gallons, 1.2 U. S. gallons	Mineralized imperial gallons, 1.2 U. S. gallons	Total imperial gallons, 1.2 U. S. gallons
1909	2,542,911	1,628,191	4,171,102
1910	2,404,019	1,558,393	3,962,412
1911	2,877,429	1,688,313	4,565,742
1912	3,091,463	1,720,031	4,811,494
1913	2,846,234	1,582,967	4,429,201

Mineralized methylated spirit is denatured by adding to 90 volumes alcohol 10 volumes of wood alcohol and three-eighths volume (0.375 per cent.) of an approved mineral naphtha. The latter is of a type that corresponds closely to the ordinary kerosine used in the United States. The mineralized methylated spirit is sold to the general public for heating, lighting and cleaning purposes.

Table VII shows the uses to which industrial alcohol (that is, alcohol used under bond which represents a part of the total used for industrial purposes) is put in the United Kingdom and the quantities consumed in the various industries for the years ended March 31, 1911–1913.

United States.

The Commissioner of Internal Revenue, in his report for 1919, states the quantities of the various raw materials used in the several states for the manufacture of alcohol, including beverage alcohol; Table VIII is based on this report. The quantities of alcohol, including beverage alcohol, which were obtained from these raw materials, are shown in Table IX. A summary of the materials used and the spirits produced therefrom during each of the fiscal years (ending on June 30) from 1913 to 1919, both included, may be found in Table X; it is of interest to compare the data for 1918 or 1919 with the average for the preceding five years. During the past few years, the production and consumption of denatured alcohol in the United States has

CHART VII.

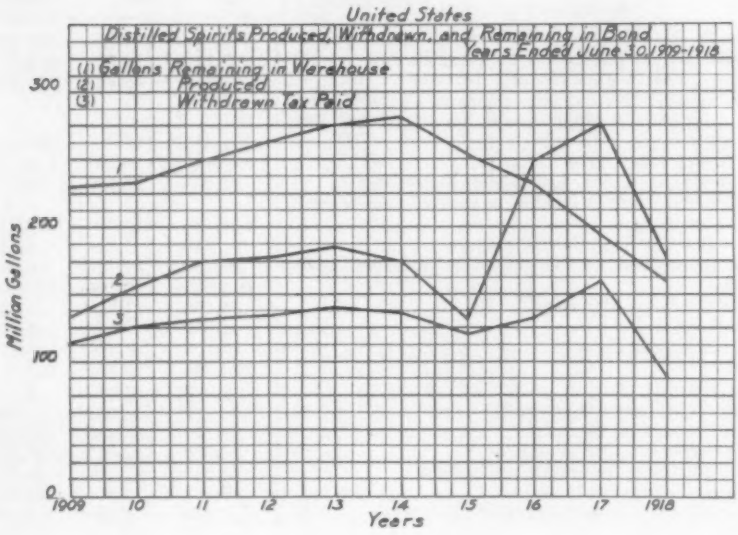


CHART VIII.

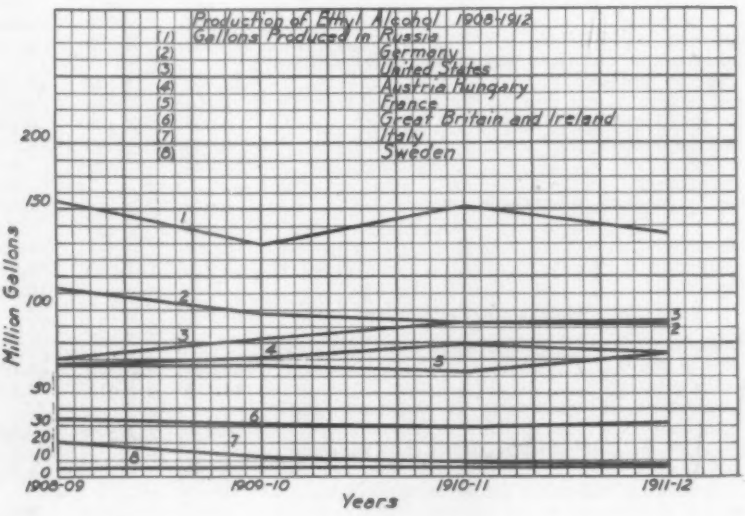


TABLE VII.

Consumption of Industrial Alcohol in the United Kingdom.

Industrial uses	Imperial gallons, 1.2 U. S. gallons		
In the manufacture of:	1911	1912	1913
Finish, for sale	369,283	419,080	395,739
Varnishes for polishes or lacquers for sale	940,186	1,030,262	983,694
Stains, paints, enamels, etc., for sale	61,176	63,242	67,546
Varnishes, finish, stains, polishes, lacquers, etc., or for polishing purposes in manufacturers' own workshops	294,343	316,863	300,325
Felt and other hats	123,430	128,001	134,742
Celluloid, xylonite, and similar substances	24,003	28,729	28,818
Oilcloths, leather cloths, pegamoid and similar substances	151,184	173,203	215,937
Linoleum and similar substances	948	398	5,340
Smokeless powders, fulminates and other explosives	20,327	21,134	19,260
Soap	144,884	160,166	180,708
Electric lamp filaments	13,151	11,835	9,151
Electric cables	4,762	1,832	5,070
Incandescent mantles	18,176	33,169	16,175
Ether	192,878	212,058	198,113
Chloroform	9,627	7,912	5,753
Ethyl chloride and bromide	747	652	806
Solid medicinal extracts	56,720	58,438	53,663
Alkaloids and fine chemicals	22,868	33,856	32,486
Embrocations, liniments and lotions	32,230	33,302	34,106
Surgical dressings	8,461	7,400	10,032
Capsules and other medicinal appliances	1,846	1,190	2,016
Hair washes	19,770	26,787	29,497
Cattle medicines	2,324	2,051	2,547
Plant washes, insecticides and sheep dips	9,630	10,763	10,877
Aniline and other dyes:			
Solids	874	1,515	211
Solutions	4,382	1,526	2,345
Fireworks and matches	5,207	4,785	3,107
Photographic plates and papers, and other photographic purposes	42,294	43,425	46,144
Steel pens	3,264	2,739	3,498
Silk, crape and embroidery	9,698	7,341	8,450
Artificial flowers, etc.	4,435	4,695	5,060
Rubber	1,223	921	586
Artificial silk	.....	.....	750
Ships' compasses, spirit levels, etc.	952	1,433	1,081
Inks	2,558	438	799
Collodion	8,302	5,331	8,191
Disinfectants	220	1,866	2,311
Hop extract	.....	.....	19,000
Other uses:			
Dyeing and cleaning operations in laundries and dye works	46,992	45,394	42,170
Textile printing	11,115	8,416	8,437
Preservation of specimens in museums and hospitals	6,850	6,562	6,608
Educational and scientific purposes in colleges and schools	6,150	6,435	5,821
Analytical and scientific purposes in the laboratories of analysts' works, chemists, etc.	4,836	6,577	5,691
For hospitals, asylums and infirmaries	43,662	47,216	51,213
Electrotyping and printing	553	1,450	1,132
Miscellaneous uses	8,573	7,671	10,905
For admiralty dockyards and war office arsenals and workshops, chiefly for varnishes and polishes	13,541	20,455	14,860
Total	2,748,635	3,008,514	2,990,870

TABLE VIII.

Grain and Other Materials Used for Production of Distilled Spirits, Year Ended June 30, 1919, by States.

States	Corn	Rye	Malt	Other materials	Molasses	Dilute saccharine liquid	Total	
	Bushels	*Bushels*	*Bushels*	*Bushels*	*Gallons*	*Gallons*	*Bushels*	*Gallons*
California	988	.....	.....	.....	11,714,888	.....	988	11,714,888
District of Columbia	111,107	.....	150,658	72,343	917,159	.....	334,108	917,159
Illinois	2,752,509	4,259	268,324	.....	12,868,046	.....	3,025,092	12,868,046
Indiana	216,957	2,930	29,463	714	.....	.....	250,064	.....
Kentucky	497,428	7,387	58,817	.....	417,637	.....	563,632	417,637
Louisiana	.....	.....	3	737	27,073,185	3,534,458	740	30,607,643
Maryland	.....	.....	129	.....	21,289,577	.....	129	21,289,577
3d Massachusetts	.....	.....	.....	.....	7,564,766	.....	.....	7,564,766
Montana	.....	.....	.....	.....	154,041	.....	.....	154,041
New York	42,830	898	5,229	.....	33,554,286	.....	48,957	33,554,286
Ohio	241,574	.....	42,833	.....	.....	.....	284,407	.....
Pennsylvania	.....	.....	.....	.....	7,945,108	.....	.....	7,945,108
South Carolina	.....	.....	.....	894	.....	6,266,877	894	6,266,877
Wisconsin	26,954	9,830	17,790	10,936	.....	.....	65,510	.....
Total	3,890,347	25,304	537,246	85,624	123,498,693	9,801,335	4,574,521	133,300,028
Total for fiscal year 1918	14,544,545	248,864	1,689,677	172,039	118,027,960	68,527,242	16,665,125	186,555,202

TABLE IX.

Production of Distilled Spirits, Years Ended June 30, 1918 and 1919, by States.

States and territories	1919			1918 Total production
	From materials other than fruit	Fruit brandy	Total production	
	Gallons	*Gallons*	*Gallons*	*Gallons*
California	8,129,788.8	1,765,905.7	9,895,694.5	14,023,646.00
Connecticut	.....	36,516.6	36,516.6	26,450.6
District of Columbia	488,214.6	.....	488,214.6	749,517.4
Hawaii	.....	.....	.....	3,934.5
Illinois	26,265,840.4	.....	26,265,840.4	49,680,080.3
Indiana	1,150,951.8	.....	1,150,951.8	15,830,930.0
Kentucky	3,957,654.8	.....	3,957,654.8	12,608,436.6
Louisiana	22,135,264.9	.....	22,135,264.9	24,406,539.3
Maryland	16,078,605.5	.....	16,078,605.5	26,746,386.2
Massachusetts	5,973,432.3	.....	5,973,432.3	10,873,374.9
Michigan	.....	.....	.....	752,744.5
Missouri	.....	.....	.....	79,526.5
Montana	107,863.4	.....	107,863.4	186,248.0
New Jersey	.....	.....	.....	51.4
New York	6,956,436.6	.....	6,956,436.6	10,544,901.1
Ohio	1,263,875.3	.....	1,263,875.3	3,314,102.9
Pennsylvania	5,877,816.5	.....	5,877,816.5	7,293,914.3
Rhode Island	.....	.....	.....	2,845.0
South Carolina	378,227.2	.....	378,227.2	943,567.7
Texas	.....	.....	.....	7,281.3
Wisconsin	212,146.2	.....	212,146.2	759,294.4
Wyoming	.....	.....	.....	26.2
Total	98,976,118.3	1,802,422.3	100,778,540.6	178,833,799.1

Total production of distilled spirits, years ended June 30, 1914–1917.

1914	181,919,542 gallons	1916	253,283,273 gallons
1915	140,656,103 gallons	1917	286,085,463 gallons

TABLE X.

Annual Domestic Production of Alcohol from Various Raw Materials.

Years	Grain used	Spirits produced from grain	Molasses used to produce spirits	Spirits produced from molasses	Molasses used to produce rum	Rum produced from molasses	Dilute saccharine liquid used to produce spirits	Spirits produced from dilute saccharine liquid
	Bushels	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*
1913	34,039,277	155,757,827	61,194,333	26,844,710	3,446,643	2,750,846	.....	.....
1914	30,679,549	142,323,044	60,862,167	29,262,516	3,859,098	3,026,085	.....	.....
1915	19,138,118	89,553,291	119,467,918	39,736,548	3,833,578	2,844,313	.....	.....
1916	39,748,892	184,091,810	77,034,173	58,052,924	3,943,301	2,908,898	71,164,758	4,070,288
1917	40,669,819	188,238,880	108,843,878	82,460,340	3,653,755	2,881,414	78,462,969	3,094,324
Total 5 years	164,275,655	759,964,852	427,402,469	236,357,038	18,736,375	14,411,556	149,627,727	7,164,612
Yearly average	32,855,131	151,992,970	85,480,493	47,271,407	3,747,275	2,882,311	74,813,863	3,582,306
1918	16,655,125	86,025,257	116,167,599	83,293,277	1,860,361	1,464,021	68,527,242	2,693,918
1919	4,574,521	21,924,557	122,498,268	75,407,358	1,000,425	816,103	34,488,066	823,000

undergone a marked increase, as may be seen by reference to Table XI.

The falling off in the quantity of denatured alcohol used during 1918 and 1919 is accounted for by the fact that in the early part of the year 1918, several of the larger munition plants discontinued the manufacture of explosives for the Allies, in which denatured alcohol had been used, and engaged in the

TABLE XI.

Domestic Production of Denatured Alcohol.

Fiscal years	Denaturing warehouses	Completely denatured	Specially denatured	Total	
		Wine gallons	*Wine gallons*	*Wine gallons*	*Proof gallons*
1907	8	1,397,861	382,415	1,780,276	3,084,950
1908	12	1,812,122	1,509,329	3,321,451	5,640,331
1909	12	2,370,839	2,185,579	4,556,418	7,967,736
1910	12	3,076,924	3,002,102	6,079,027	10,605,870
1911	14	3,374,019	3,507,109	6,881,129	11,682,887
1912	14	4,161,268	3,933,246	8,094,515	13,955,903
1913	21	5,233,240	4,608,417	9,831,658	16,953,552
1914	25	5,213,129	5,191,846	10,404,975	17,811,078
1915	23	5,386,646	8,599,821	13,986,468	25,411,718
1916	33	7,871,952	38,807,153	46,679,106	84,532,253
1917	44	10,508,919	45,170,678	55,679,597	93,762,422
1918	49	10,328,454	39,834,561	50,163,016	90,644,722
1919	45	9,976,721	28,294,219	38,270,940	59,976,575

manufacture of explosives for the United States Government, using principally tax-free undenatured alcohol. The Army specifications were subsequently changed, and denatured alcohol was used exclusively in those plants. The quantity of denatured alcohol used during the year 1918 in the manufacture of explosives and for other war purposes was approximately 52,847,117 proof gallons.

USES OF INDUSTRIAL ALCOHOL.

Every chemist realizes the impossibility of even enumerating all of the uses of alcohol; the more study one gives to the uses of alcohol the more he is impressed with the great multitude of products of all descriptions which depend directly or indirectly on the use of alcohol in their manufacture.

USE OF ALCOHOL AS A SOLVENT.

Undoubtedly the most important use of alcohol is that of a solvent. Chemists and pharmacists are convinced that the only solvent which is of even equal importance is water.

The use of alcohol as a solvent in the manufacture of nitrocellulose, and in purification processes, has been demonstrated during the war in the manufacture of munitions. Alcohol as such is not a solvent for nitrocellulose, but when mixed with ether it is used in large quantities in the manufacture of smokeless powders and collodion.

Alcohol as a solvent for dyes and confectioner's colors is of great importance. The development of gelatine food products has also called for considerable quantities of alcohol as a solvent for the coloring matter and as a vehicle for its introduction. A great many colors are sold in the form of a solution in alcohol or a paste.

No suitable substitute has ever been found for many of these uses of alcohol; and if that compound were not available, many industries would be greatly restricted, and many others would cease to exist. If it were not for the solvent properties of alcohol we should have very few of such things as perfumes, liquid soaps, toilet waters, liniments, flavoring extracts, etc.

Practically all of the paint and varnish removers on the market depend, for their action, to a greater or less extent upon the solvent properties of alcohol; and many of the shellacs and varnishes themselves are made up with alcohol as a solvent and thinner.

ALCOHOL AS A FUEL.

The United States has been very fortunate indeed in that it has had very abundant supplies of petroleum. For that reason alcohol has not been used very extensively for fuel and power purposes. However, these supplies of petroleum are not inexhaustible, and already steps towards the conservation of these resources have been taken. The United States Geological Survey, after a very careful analysis of the situation, finds that the reserves above ground are being rapidly depleted. They predict that the peak in petroleum production will be reached in from two to three years, and that after that time there will be a gradual decline in production over a period of years.

Although the petroleum resources are being depleted, the raw materials for the production of alcohol are about us in inexhaustible quantities; and these resources may be renewed constantly. Alcohol is a very superior fuel in that it burns with a smokeless flame and does not carbonize like kerosene; and even

at the present time, its only rival for chafing dishes, coffee percolators, and such articles is electricity.

In regions where electricity is not available alcohol has no rival for cooking, heating, lighting and many other purposes. Alcohol when burned under a Welsbach mantle, which depends upon heat for its luminosity, makes a most satisfactory light. It gives three and a half times as much light as the same volume of kerosene when burned in a good oil lamp. The cleanliness and freedom from odor make alcohol very desirable for this purpose.

Concerning the utilization of alcohol for power purposes there is still much to be said. On account of our enormous petroleum resources, no great amount of alcohol has been used in the United States for power purposes, but such use has been very extensive abroad. However, as our petroleum resources become exhausted, alcohol as such, and in admixture with other products, will assume a very important rôle among the fuels for power purposes, especially in the automotive field. Even though it is true that, pound for pound, gasoline has a higher calorific value than alcohol, yet, under the conditions found in ordinary gasoline engines, the theoretical power is never developed. This has been especially true during the last two or three years, since the gasoline has included more of the higher boiling compounds, and vaporization and atomization of the fuel has become increasingly difficult. The point has now been reached where the average gasoline engine utilizes only a relatively small portion of the fuel used. Thus, if an engine burning gasoline be compared with a properly-designed engine using alcohol as fuel, it is found that the power developed per gallon of fuel is about the same. As the price of gasoline increases and as its quality becomes poorer, both of which will happen according to the U. S. Geological Survey, alcohol will attain an ever-increasing importance in this field. An instance may be cited to show the possibilities of the use of alcohol in admixture with other components for motor fuel purposes. During the last year at least one of the larger producers of industrial alcohol has devoted some attention to the production of an alcohol fuel. A mixture of alcohol, gasoline and other components has been developed which possesses remarkable properties, and is much more efficient as a fuel, when compared with gasoline under identical conditions.

The above statements are emphasized by the results obtained by the Post Office Department. The planes used in the United States Post Office Airplane Mail Service are being operated with an alcohol fuel. The Post Office Department tests show a great increase in the number of miles per gallon, an increase in power, and a very marked saving in the quantity of lubricating oil used.

The following is an analysis of the consumption of alcohol fuel at the various speeds, the tests covering thirty-one non-stop flights between New York and Washington:

1440–1460 r. p. m.	15.9	gal. per hour
1475–1480 r. p. m.	20.1	gal. per hour
1500 r. p. m.	21.5	gal. per hour
1520–1525 r. p. m.	22.44	gal. per hour

A comparative analysis of the fuel consumption with gasoline and alcohol fuel at different engine speeds follows:

R. P. M.	1440-1460	1475	1500
Gasoline		24	24.17
Alcohol fuel	15.9	20.1	21.5

The following is a comparative analysis of lubricating oil consumption at different engine speeds:

R. P. M.	1440-1460	1475	1500
Gasoline		4.65	4.95
Alcohol fuel	4.5	4.2	4.2

These tests also show much less carbon formation than when using gasoline; and the number of forced landings due to fouled spark plugs has been reduced to a minimum.

The U. S. Bureau of Standards has been making exhaustive tests on blended alcohol fuels. The results of these tests are available at that Bureau and are indeed indicative of the superiority of these alcohol fuels over those ordinarily obtainable.

The following quotation concerning the use of this alcohol by the Post Office Department is from *The Journal of the Society of Automotive Engineers* (vol v, No. 3, p. 207):

> A new alcoholic fuel, consisting of alcohol, benzol, and ether, is about to take the place of the high-grade airplane gasoline, which has previously been used in the Air Mail Service.
>
> The advantage of this fuel lies in the resulting cleanliness of the engines, reduction of the cost of upkeep and its burning cooler than gasoline, which, to some extent, overcomes the objection to a high-compression

engine when operating at low altitudes. It requires about four-fifths as much of the new fuel for any given distance and altitude. This gives greater flying radius to the planes and will enable the De Haviland Fours to cover the New York to Cleveland route, a distance of 430 miles, in a non-stop flight. It reduces the probability of forced landings by keeping the spark-plugs and the engine cylinders clear of carbon deposits and accumulations of oil.

ALCOHOL AS A RAW MATERIAL IN CHEMICAL PROCESSES.

A great many chemical processes depend directly on alcohol as a raw material. Probably, in normal times, the most important and extensive use of this type is the manufacture of the ethyl esters. These esters are used very extensively as solvents in the production of pyroxylin plastics, films, artificial leather, celluloid, etc.

In the world war enormous quantities of alcohol were used as raw material for the production of toxic gases such as mustard gas. The mustard gas was formed as follows:

By a process of catalytic dehydration ethylene was formed from alcohol. The ethylene was then passed through sulphur monochloride S_2Cl_2 when combination took place forming mustard gas.

$$\begin{matrix} C_2H_4 \\ C_2H_4 \end{matrix} + S_2Cl_2 \longrightarrow \begin{matrix} ClC_2H_4 \\ ClC_2H_4 \end{matrix} \diagdown S + S$$

Dichlor-diethyl sulphide
or
Mustard Gas

Other very important uses of alcohol as raw material occur in the manufacture of ether, mercury fulminate, chloroform, acetphenetidin, and a very large number of other drugs and chemicals. Alcohol is used as a raw material for the production of acetaldehyde. The aldehyde is formed directly by the catalytic oxidation of alcohol in a tubular retort.

ALCOHOL AS A GENERAL UTILITY.

The innumerable uses of alcohol in the hospital, in the chemical laboratory, and in the home are so well known to almost everyone that even a mention of them seems unnecessary. How many of our hospitals could operate effectively without the use of alcohol? How many of our chemical laboratories could carry on their work successfully without the use of alcohol? Alcohol is so useful about every household, for such purposes as a fuel, for

cleaning and as an ablution, that even if not a necessity it would be an inconvenience if necessary to do without it.

MISCELLANEOUS USES OF ALCOHOL.

Alcohol is used in large quantities as a dehydrating agent in the manufacture of photographic films and in the preparation of photoprints.

Oftentimes in cases of substances insoluble in alcohol, alcohol is very valuable as a precipitating and purifying agent. Among such products may be mentioned glycero-phosphates, casein and milk protein, lanolin, etc.

Alcohol is frequently necessary as a solvent in the manufacture of such things as inks, celluloid and shellac cements, disinfectants, etching solutions, soldering fluxes, etc.

Alcohol as such, and in admixture with other compounds, has been used extensively as a carbon remover. The carbon deposits formed in the cylinders of automotive engines resist the action of most solvents. Alcohol and a few other compounds seem to have the property of acting as a solvent for the binder of such deposits, thus freeing the carbon and siliceous materials which are allowed to blow out through the engine exhaust.

The U. S. Bureau of Standards has made exhaustive tests of all the important anti-freeze preparations for preventing the freezing of the water in radiators of automotive apparatus. After this careful study they recommend the use of alcohol. Practically all of the high-class motor-car manufacturers recommend the use of alcohol for this purpose. Most anti-freeze preparations contain calcium chloride, which causes excessive corrosion of the cooling system according to the Bureau of Standards; this statement is supported by the recent discussion of the question at the Buffalo meeting of the American Chemical Society. Alcohol is no more corrosive than pure water and its use as an anti-freeze is becoming very extensive.

Alcohol is used in the preparation of all forms of manufactured tobacco. Practically all of the so-called "casing" solutions are made up with alcohol.

FUTURE OF INDUSTRIAL ALCOHOL.

The future of industrial alcohol is only limited by the restrictions which may surround its use. Now that the United States

has gotten a start in the chemical and allied industries in which alcohol is an absolute necessity, development should be rapid and extensive.

After the passage of the industrial alcohol law in 1906 the effect on American industries was marked. Many new enterprises were undertaken, and those in operation were greatly expanded. An export trade was undertaken and developed until to-day the export of alcohol, and products in the manufacture of which alcohol is a necessity, is a very important factor.

The Internal Revenue Bureau regulations which have just been released make possible the utilization of alcohol for industrial purposes to a greater extent than ever before. For example, it is now possible for chemical laboratories to obtain pure ethyl alcohol free of tax for use in scientific research. It is also possible for schools, colleges, hospitals and sanatoriums to obtain alcohol free of tax.

Some of the needless formalities surrounding the manufacture, sale, and use of denatured alcohol have been eliminated, and the manufacturer using alcohol is thereby helped. May we not hope that the Internal Revenue Bureau will continue its present open-minded policy and encourage the proper use and regulation of industrial alcohol.

CONCLUSIONS.

Although a treatise of several volumes would be required to discuss industrial alcohol in a thorough manner, yet it is hoped that a few suggestions have been given which will indicate to the reader the nature and scope of the alcohol industry and the vast number of other industries in which industrial alcohol is a necessity, and that a realization of the great importance of industrial alcohol will be acquired.

Now that the world at large realizes in a measure the difference between beverage and industrial alcohol, may we not look for favorable legislation concerning industrial alcohol and a stimulation of those industries which have not yet attained their proper expansion in the United States? May our industries using alcohol be enabled to compete with those of any other country.

THEORY AND PRACTICAL ATTAINMENTS IN THE DESIGN AND USE OF RADIO-DIRECTION FINDING APPARATUS USING CLOSED COIL ANTENNAS.*

BY

A. S. BLATTERMAN.

Captain Signal Corps, U. S. Army.

(SUPPLEMENTARY NOTE.)

INFORMATION concerning coil receivers for wave-lengths below 1000 metres has already appeared in this JOURNAL [1] in connection with the data for longer wave-lengths. The following results on 4′ and 6′ loops for ¼″ and $^{7}/_{16}$″ wire spacing, respectively, which values correspond to the best values of spacing for these sizes of loops as determined by the curve, Fig. 21, page 309, of the original paper, have recently been obtained:

Four-foot Loop—¼″ Spacing.

Four turns.		Seven turns.		Ten turns.	
Wave-length.	Resistance.	Wave-length.	Resistance.	Wave-length.	Resistance.
220 metres	14.8 ohms	330 metres	10.5 ohms	450 metres	13.2 ohms
275 metres	3.95 ohms	390 metres	7.5 ohms	600 metres	6.8 ohms
350 metres	2.65 ohms	450 metres	5.55 ohms	800 metres	4.55 ohms
450 metres	2.15 ohms	600 metres	3.6 ohms	1000 metres	3.6 ohms
600 metres	1.6 ohms	1000 metres	2.5 ohms	1400 metres	2.8 ohms
800 metres	1.4 ohms				

Six-foot Loop—$^{7}/_{16}$″ Spacing.

Three turns.		Five turns.		Seven turns.	
180 metres	11.4 ohms	275 metres	20.0 ohms	400 metres	20.0 ohms
260 metres	5.5 ohms	305 metres	12.9 ohms	550 metres	8.6 ohms
360 metres	3.4 ohms	400 metres	6.5 ohms	750 metres	6.0 ohms
500 metres	2.5 ohms	500 metres	4.6 ohms	1200 metres	3.4 ohms
750 metres	2.0 ohms	750 metres	3.0 ohms		
1000 metres	1.9 ohms				

Ten Turns.

660 metres	22.6 ohms
600 metres	17.2 ohms
750 metres	10.5 ohms
1000 metres	6.5 ohms
1500 metres	4.4 ohms

* Communicated by Maj.-Gen. George Owen Squier, Chief Signal Officer, U. S. A.

[1] Vol. 188, page 289 (September, 1919).

Motor Transportation in Palestine. (*Scientific American*, August 7, 1920, p. 121.)—The camel is being superseded by the motor vehicle and soon cars and trucks will be numerous in the streets of Jerusalem and other ancient cities of Palestine, and will also be employed for interurban transportation. The slow-moving, but fairly reliable, camel is to be replaced by the faster and more reliable motor truck mechanism. The problem of transportation not only in Jerusalem but throughout Palestine is acute. The railroads are few in number and uncertain in their schedules. Most of the passenger service of these roads was suspended during the war except for the use of troops. These roads are now in such a condition as to make other means of transportation necessary. The English since their occupation have been building up the important ports of Palestine and are planning to operate a fleet of motor trucks to these places to accommodate the influx of tourists to the birthplace of Christianity and to accommodate commercial travellers. A service from Jerusalem to Damascus in Syria is also being planned.

Preservation of Eggs.—HILTON I. JONES and ROBERT DU BOIS of the Oklahoma Agricultural and Mechanical College (*Journal of Industrial and Engineering Chemistry*, 1920, xii, 751–757) divide the methods for the preservation of eggs into four classes: (1) Cold storage; (2) air-tight packing; (3) sealing with various agents, and (4) immersion in preservative solutions. Of the various sealing agents, aluminium soap was found the most efficient. When gasoline was used as a solvent for this soap, the shell eggs were dipped first in dilute sulphuric acid, then in the soap solution; by this procedure the eggs remained free from any taste of gasoline. When chemically pure pentane was used as the solvent, the soap solution alone was applied to the eggs. Pentane was readily obtained by hydrogenation of amylene which was prepared from technical fusel oil. Exposure of the eggs to a high vacuum (several mm. of mercury) without the use of a preservative exerted a bactericidal action, but did not entirely preserve the eggs. J. S. H.

Kelp distillates have been studied by G. C. SPENCER (*Journal of Industrial and Engineering Chemistry*, 1920, xii, 786–792). In the destructive distillation of kelp in closed retorts for the recovery of potassium chloride and iodine, a tar is obtained which may be separated into tar acids, neutral oils, ammonia, and pitch. The crude tar creosote (tar acids) has a high toxicity and may be used as a disinfectant. The residual kelp oil has value as a flotation oil. The pitch residue from the distillation of the tar is a source of nitrogen for Prussian blue and other compounds of cyanogen. The aqueous liquor, obtained in the distillation, contains ammonia in workable quantities. J. S. H.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

ENAMELS FOR SHEET IRON AND STEEL.[1]

By J. B. Shaw.

[ABSTRACT]

THIS is a general treatise dealing with the technology of enameling of sheet iron and steel. It has been prepared to answer the demand for a general treatise dealing with the technology of the manufacture of vitreous enamels for these metals. This subject is not treated adequately in any existing publication.

From the standpoint of mechanical equipment the sheet-iron and steel enameling industry has been probably the most progressive of all ceramic industries in the United States. The presses and machinery used for working the steel and forming the shapes are unsurpassed in ingenuity by those used in any other industry, and are constantly being improved. In this respect the sheet-metal enameling industry of this country has led the world. In the strictly ceramic lines of the industry having to do with the preparation and application of the enamels, progress has been less rapid. Up to a few years ago there was very little work carried on and this little was seldom reported in print. Recently there has been a decided change in this respect. Representatives of the enameling industry have been joining the ceramic technical societies, have been contributing rather liberally to the journals of these organizations, and have been showing a decided interest in developing the technology of sheet-metal enameling. The leading manufacturers of the country are realizing that the sheet-iron enameling industry has reached the limit of development possible so long as it depends upon formulas rather than upon men with technical training which will enable them to improve and manipulate these formulas to meet varying conditions.

In collecting data for this paper an effort has been made to obtain reliable and authentic information wherever available and

* Communicated by the Director.

[1] Technologic Paper No. 165.

to correlate it in such a manner as to shed some light on the problems encountered by enamelers. The treatise is a compilation of data dealing with the subject of enameling from various publications, from the notebook of the author, from the files of the Bureau, and from the experience of men engaged in the enameling industry in this country.

Among the subjects dealt with in connection with the properties and preparation of steel for enameling are physical and chemical requirements, sand blasting, treatment preliminary to pickling and methods of pickling. A chapter is devoted to the properties of the raw materials used in compounding enamels. The relations between chemical composition and physical properties of enamels are discussed fully. The procedure used in the preparation, applying and firing of enamels are described in detail. The calculation of enamel formulas is fully explained and examples are given. The physical properties of enamels are dealt with in some detail and resistance of enamels to chemical action is fully discussed.

ADJUSTMENT OF PARABOLIC AND LINEAR CURVES TO OBSERVATIONS TAKEN AT EQUAL INTERVALS OF THE INDEPENDENT VARIABLE.[3]

By Harry M. Roeser.

[ABSTRACT]

LEAST squares reductions of observations that follow a parabolic or linear law taken at equal intervals of the independent variable frequently occur in physics and engineering practice. Makeshift devices are often employed to evade the arithmetical work of determining the constants of curves which properly represent such data.

In this paper the ordinary least squares formulas are subjected to mathematical treatment and rigorous solutions are evolved which require an ultimate minimum of arithmetical work. A table is furnished from which a large portion of the solutions can be written down from inspection of the observations.

Application of the solutions is made to typical problems and an absolute check with the regular least squares solutions is shown.

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[3] Scientific Paper No. 388.

THE MEASUREMENT OF DIFFUSE REFLECTION FACTORS AND A NEW ABSOLUTE REFLECTOMETER.[1]

By A. H. Taylor.

[ABSTRACT]

THE diffuse reflection factor of a surface is the numerical value of the ratio of the total reflected light flux to the incident light flux.

The measurement of reflection factors of surfaces such as walls and ceilings is of considerable value in planning the lighting of offices, etc. Previous to this time there has been no accurate and convenient instrument available for this purpose. Several methods have been used in making such measurements in the laboratory, but most of them have been incorrect, on account of an erroneous value assigned to the standard surface. Hence it is apparent that an "absolute" reflectometer (one not requiring a reproducible standard surface) which is both reliable and portable would fill a very real need. Such an instrument has been developed and tested by the author, with satisfactory results.

The new reflectometer consists of a hollow sphere, with a segment of the surface cut off. It is painted white inside, and light is projected through a small hole in the wall onto the sphere wall, or onto the test surface over the opening. It can be adapted to use with any good type of portable photometer, and will give absolute, not relative, reflection factors.

The instrument has been checked by measurements by an independent method, and was found to give correct results when used as recommended.

Magnesium carbonate has usually been used as the standard when measuring reflection factors by several laboratory methods, the assigned value being 88 per cent. Measurements by four absolute methods showed that the factor was approximately 99 per cent. for one block, and 98 per cent. for another.

The paper gives a complete description of the theory and tests of the new instrument, as well as a description of the various reflectometers which have been used in the past.

[1] Scientific Paper No. 391.

AUTOMATIC APPARATUS FOR INTERMITTENT TESTING.[4]

By G. W. Vinal and L. M. Ritchie.

[ABSTRACT]

THIS apparatus has been devised to meet the needs of the Bureau of Standards in making tests of dry cells and storage batteries, but is applicable to nearly any form of intermittent testing requiring the closing of electrical circuits at regular time intervals. The particular advantages of this type of apparatus for making these tests are: (1) elimination of rapidly-moving parts; (2) accuracy of the time intervals; (3) possibility of making a number of different tests simultaneously with the same apparatus.

RELATIVE SPECTRAL TRANSMISSION OF THE ATMOSPHERE.[5]

By Dr. E. Karrer and E. P. Tyndall.

[ABSTRACT]

DATA on the transmission of light by the atmosphere are essential in order to compare various searchlight beams whose characteristics are invariably obtained at different times and under different atmospheric conditions; and are also essential in all considerations as to what the color of a searchlight beam should be to obtain best results. For these latter considerations the relative spectral transmission of the atmosphere is required. Not only are such data on the spectral transmission of the atmosphere of value to the theory and practice of searchlight illumination but are also of prime importance to an intelligent consideration of headlamps for automobiles and locomotives, as well as to the selection and development of color schemes and emulsions for use in aerial photography.

The method consisted in comparing, wave length for wave length, the intensity of a ray of light emitted by an incandescent lamp, after reflection from a mirror 600 mμ distant with that of a ray directly entering the spectrophotometer near the lamp. Either of these rays could be allowed to enter one of the collimators of a Brace spectrophotometer, to be compared alternately

[4] Technologic Paper No. 171.
[5] Scientific Paper No. 389.

in intensity with a beam from the same incandescent lamp entering the second collimator. The photometric balance was obtained by varying the slit width of this second collimator admitting the comparison beam.

Data on the relative spectral transmission are given, (1) for a clear atmosphere, (2) for the atmosphere of high humidity, and (3) during rains. The curves for (1) show little selectivity. Between wave lengths 520 and 660 mμ the transmission is uniform. At 660 it begins to decrease. Also from 520 to 440 mμ it gradually and continuously decreases. The curves for the atmospheric condition of (2) and (3) are almost identical for the region from 430 to 560 mμ, the transmission increasing with the wave length. In the region from 560 to 670 mμ the curve for the rainy atmosphere shows a maximum near 640 mμ, while that for the atmosphere of high humidity indicates two maxima, at 580 and at 650 mμ, with a minimum near 620 mμ. The decrease at 660 mμ in both cases is very similar to that noted for the clear atmosphere, and is probably to be associated with the absorption band of the oxygen of the atmosphere.

The data show that under weather conditions such as prevailed during the experiments the light in the orange region of the spectrum will be transmitted by the atmosphere with least relative depletion. In applying these data, however, due consideration must be made of other factors that are of importance to good seeing under various conditions of illumination.

THE TWO COMMON FAILURES OF THE CLARK STANDARD CELL.[8]

By E. C. McKelvy and M. P. Shoemaker.

[ABSTRACT]

THE International Electrical Congress of 1893 adopted the Clark cell as the international standard of electromotive force. In 1908 The International Conference on Electrical Units and Standards selected the Weston Normal Cell as the more satisfactory standard. One of the chief factors influencing this change was the large percentage of failures of Clark cells through cracking of the cell wall about the sealed-in negative terminal, and through the formation of gas in the amalgan limb.

[8] Scientific Paper No. 390.

It is shown that the cracking of the cell can be prevented by sealing into the cell wall for the negative terminal platinum wire previously subjected to the action of zinc amalgam, and that the effects of the formation of gas can be minimized through the employment of the smallest excess of crystals required to insure saturation at the highest temperature at which the cell is likely to be used.

PHOTOGRAPHIC METHOD OF DETECTING CHANGES IN A COMPLICATED GROUP OF OBJECTS.[1]

By M. H. Stillman.

[ABSTRACT.]

A NEGATIVE is made of the group of objects in which a change is expected. After the change is supposed to have occurred, a second negative of approximately the same density as the first is made with the same camera (or one of the same kind) on a plate of the same kind and from as nearly as possible the same position as used in making the first negative. A positive is printed from one of the negatives, is superposed upon the other negative so as to bring them into register, and the combination viewed against a source of light. When the photographs are properly made, those parts of the combination which correspond to the unchanged portion of the group of objects, will appear as a field of practically uniform density, while a change in the group will be revealed by a considerable departure from this uniform density.

It is very desirable to make the negatives and positive of considerable contrast and at the same time confine all exposures to the straight-line portions of the characteristic curves. To secure the best results the positive should have a contrast equal to the ratio of the contrast of the negative superposed upon the positive to the contrast of the negative from which the positive is derived.

The method has for some time been used to a limited extent in astronomy and physics. It was independently devised by the present author about three years ago and developed for camouflage detection, engineering and other purposes in coöperation with Dr. H. E. Ives of the United States Air Service.

[1] Scientific Paper No. 392.

NOTES FROM NELA RESEARCH LABORATORY.*

NELA RESEARCH LABORATORY was organized in 1908 under the Directorship of Dr. Edward P. Hyde as The Physical Laboratory of the National Electric Lamp Association. The name was changed to Nela Research Laboratory in 1913, when the National Electric Lamp Association became the National Lamp Works of General Electric Company. For some years the Laboratory was devoted exclusively to the development of those sciences on which the art of lighting has its foundation, but in 1914 the functions of the Laboratory were extended by the addition of a small Section of Applied Science, which had an immediate practical objective.

The Section of Applied Science is now being largely extended as a separate Laboratory of Applied Science under the immediate direction of Mr. M. Luckiesh, who becomes Director of Applied Science, and a new building is being constructed to house this branch of the work, which will be carried forward with a staff of several physicists, an engineer, an architect and a designer, together with the necessary technical and clerical assistants.

Dr. Ernest Fox Nichols, formerly President of Dartmouth College, and more recently Professor of Physics at Yale University, has accepted an invitation to assume the immediate direction of the Laboratory of Pure Science, under the title of Director of Pure Science. The work of this Laboratory, which will be continued in the present building, will be somewhat further extended under the new organization.

The Laboratory of Pure Science and the Laboratory of Applied Science will together constitute the Nela Research Laboratories, and will be coördinated under the general direction of Doctor Hyde, who becomes Director of Research.

* Communicated by the Director.

Decolorizing Carbon.—While finely divided carbon has been used to decolorize solutions, but little study has been made of its action in the removal of other substances from their solutions. JOSEPH C. BOCK, of Marquette University (*Journal of the American Chemical Society*, 1920, xlii, 1564–1569), has investigated the properties of "Norit," a finely divided vegetable carbon. Most of the experiments were made on urine; a 100 c.c. sample of urine was shaken with Norit, of which 5 grams were usually, though not invariably, used. The shaking was not of necessity very prolonged or especially vigorous; the requisites were good mixing, and an even distribution of the Norit throughout the liquid. From the urine Norite removed: Ammonia, glucose, and chlorides slightly; urea, total nitrogen, and phosphates to a considerable extent; creatinine very largely; uric acid completely. The adsorption of these solids from their solution in the urine by the Norit was specific and selective. When several solutes were present in a solution, each of them was adsorbed by Norit to a lesser extent than when present separately. Norit decreased the bacterial count of bouillon cultures, but did not produce sterility. The adsorptive power of Norit was somewhat increased by successive treatment with dilute hydrochloric acid water, dilute alkali, and, finally, washing until neutral in reaction.

J. S. H.

Response of Cottonseed Oil Products to the Kreis Test for Rancidity.—In the Kreis test a fat or oil is shaken with equal volumes of hydrochloric acid and a solution of phloroglucinol in ether. The development of a red color indicates that the fat or oil is rancid; its formation is probably due to the presence of aldehydes or ketones in the material tested. Chromogenetic substances, which give a positive Kreis reaction, occur in crude cottonseed oil. The researches of W. B. SMITH (*Journal of Industrial and Engineering Chemistry*, 1920, xii, 764–766) show that refined cottonseed oils and their products at times contain these chromogenetic substances, carried over from the crude oil. These substances sometimes cause a positive Kreis reaction by a non-rancid oil; and hence the value of the positive Kreis test as evidence of rancidity is greatly lessened in the case of cottonseed oil.

J. S. H.

The World's Rainfall. (*U. S. Geol. Surv. Press Bull. No. 452*, July-August, 1920.)—The total annual rainfall upon all the land of the globe amounts to 29,347 cubic miles, and of this quantity 6524 cubic miles drains off through rivers to the sea. A cubic mile of river water weighs about 4,205,650,000 tons and carries in solution an average of about 420,000 tons of foreign matter. In all, about 2,735,000,000 tons of solid matter is thus carried annually to the ocean.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

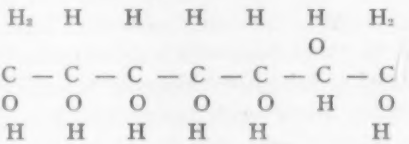
SEDOHEPTOSE, A NEW SUGAR FROM SEDIUM SPECTABILE II.[1]

By F. B. La Forge.

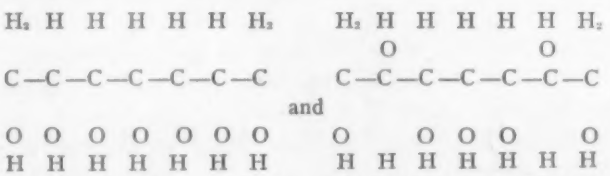
[ABSTRACT]

SEDOHEPTOSE was discovered in the leaves and stems of sedum spectabile, a cultivated plant commonly used for ornamental purposes. The sugar was isolated and characterized as ketose, after which a number of derivatives were prepared as described in a previous article.[2]

Upon reduction of sedoheptose with sodium amalgam, two heptitols, one active and one inactive, were formed. The active (α) sedoheptitol has the configuration,



There are two possibilities with respect to the configuration of the inactive sedoheptitol (β),

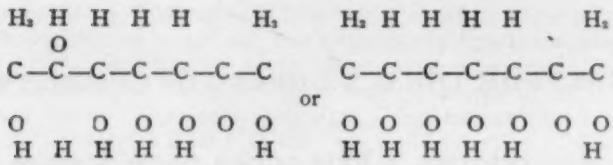


Sedoheptose is shown to be an alpha ketose to which one of the two possible formulas,

* Communicated by the Chief of the Bureau.

[1] Published in *J. Biol. Chem.*, **42** (1920), 367.

[2] Published in *J. Biol. Chem.*, **30** (1917), 61.



must be assigned.

This point can be decided when the active and one of the two inactive heptitols resulting from its reduction are prepared from heptoses of known configuration.

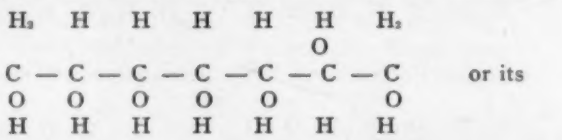
VOLEMITE.[3]

By F. B. La Forge.

[ABSTRACT]

THE natural heptitol volemite described by Bourquelot and Fischer was shown in a previous article[4] to be very similar in properties to α sedoheptitol obtained from sedoheptose by reduction.

A sample of natural volemite obtained later was found to correspond in all its properties with α sedoheptitol. In addition to other derivatives of sedoheptitol already described, its acetal was prepared by condensation with acetaldehyde. This compound showed $[\alpha]_D$ in chloroform solution $= -45.55$ which agreed with the rotation given for volemite acetal by Bougault and Allard.[5] The melting points of the two heptitols were identical and the mixed melting point showed no depression. As the formula



or its mirror image as shown in the article must be the formula for sedoheptose, this must also be the one which corresponds to volemite.

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[3] Published in *J. Biol. Chem.*, **42** (1920), 375.

[4] *J. Biol. Chem.*, **30** (1917), 61.

[5] *Compt. rend.*, **135** (1902), 796.

THE ODOROUS CONSTITUENTS OF APPLES. EMANATION OF ACETALDEHYDE FROM RIPE FRUIT.[a]

By Frederick B. Power and Victor K. Chestnut.

[ABSTRACT]

No information of a definite nature has hitherto been recorded with respect to the odorous constituents of apples, and although preparations designated as "apple oil" or "apple essence" have long been in use, these have consisted entirely of artificial products. Moreover, many of the components of such preparations are now known not to be contained in the apple, and some of them do not even occur in nature.

In order to elucidate the subject, a complete investigation was undertaken in the Bureau of Chemistry of the United States Department of Agriculture, as a result of which the following facts have been established:

1. The odorous constituents of apples consist essentially of the amyl esters of formic, acetic, and caproic acids, together with a small amount of the caprylic ester and a considerable proportion of acetaldehyde.

2. Acetaldehyde is a product of the vital activity of the fruit, and occurs in the exhalation from ripe apples.

3. In addition to the substances mentioned in paragraph 1, the aqueous distillate from fresh apple parings contains exceedingly small amounts of methyl and ethyl alcohols as well as a little furfural. As the last-mentioned compound is only produced during the process of distillation, it does not represent an odorous constituent of the fruit.

4. The essential oil from apples is at ordinary temperatures a yellowish, somewhat viscid liquid, which becomes darker on keeping. When slightly cooled, it forms a concrete mass, due to the separation of small acicular crystals which consist of a paraffin hydrocarbon. It possesses in a high degree the characteristic fragrant odor of fresh apples. Besides the esters mentioned, it contains small amounts of acetaldehyde and furfural. The yield of oil from the parings of the Ben Davis apple was 0.0035 per cent., and that from the more odorous crab-apple

[a] Published in *J. Am. Chem. Soc.*, 42 (1920), 1509.

0.0043 per cent., representing 0.0007 and 0.0013 per cent., respectively, of the entire fruit.

5. Although in chemical literature amyl valerate is generally designated as "apple oil," it is quite certain that this compound has never been found in the apple, and in the recent investigation no evidence could be obtained of its presence. On the other hand, the characteristic, fragrant odor of ripe apples has now been shown to be due to a combination of the substances enumerated above. These substances may exist in varying proportions in the numerous varieties of the fruit, thus causing slight differences in odor.

Starch Content of Silage.—ARTHUR W. DOX and LESTER YODER (*Journal of Agricultural Research*, 1920, xix, 173–179) made chemical analyses of corn silage at various stages of its fermentation. The fermentation was normal with respect to development of aroma and changes in acidity, alcohol, and sugar content; these changes were entirely independent of the starch content of the ensiled corn and of the silage produced from it. The first intermediate products, which form in the decomposition of starch, *i.e.*, soluble starch and dextrins, were never present in demonstrable quantities; and the starch content remained constant throughout the process of fermentation. The starch granules remained intact, and underwent no change which could be detected by microscopic examination. "Since starch constitutes about 10 per cent. of the corn plant at the time of ensiling and represents over 400 calories of available energy per kilogram, the fact that no loss occurs during fermentation is an additional argument in favor of silage as an economical feed."

J. S. H.

Melting Points and Thermoelectric Behavior of Lead Isotopes.—THEODORE W. RICHARDS and NORRIS F. HALL, of Harvard University (*Journal of the American Chemical Society*, 1920, xlii, 1550–1556), used two isotopes—ordinary lead and Australian radioactive lead—in their research. While the two isotopes differed in atomic weight by 0.8, the difference in their melting points, if appreciable, did not exceed 0.05° C. "It is fairly safe to assume that the kinds of lead not only have very nearly the same melting point, but also (since the sample consisting chiefly of the lighter isotope doubtless contained ordinary lead) they mix (or rather mutually dissolve) without affecting the melting point." The Seebeck thermoelectric effect produced at a junction of the two isotopes was shown to be *nil*.

J. S. H.

NOTES FROM THE U. S. BUREAU OF MINES.*

INDICATORS FOR CARBON DIOXIDE AND OXYGEN IN AIR AND FLUE GAS.

By L. H. Milligan.

THERE is a distinct need for simple, compact, portable instruments that will indicate quantitatively the proportions of CO_2 and of oxygen in air that people who work in confined places must breathe, and also the CO_2 content in flue gases.

Apart from the presence of toxic gases like CO, the greatest danger to men working in inclosed places comes chiefly from an increase in CO_2 or decrease in oxygen content of the air breathed. These conditions generally accompany each other, as processes of organic oxidation, such as fires, breathing of men, surface oxidation of coal in a coal mine, convert the oxygen of the air into CO_2. When a man breathes air containing more than 2 per cent. CO_2 for any considerable period, his working efficiency is reduced, and he is in considerable danger when the air contains more than 4 per cent. CO_2 or less than 13 per cent. oxygen. Instruments with which CO_2 and oxygen can be determined will give warning of danger in time to avert it.

Fuel is burned most efficiently when the oxidation is complete, and in burning coal, coke, petroleum, natural gas, or other fuels, this condition is most nearly met when the flue gases have a high CO_2 content. Therefore, one method of maintaining high efficiency in a power plant is to make frequent determination of the CO_2 in the flue gases.

In the laboratory, air or gas analyses are made with stationary apparatus, but in the field portable types must be used. Various portable devices have been designed and marketed, but in general they have been bulky. heavy, more or less fragile, and require a trained chemist to operate them.

The Bureau of Mines, with a view to overcoming these objections, has developed three types of portable indicators in its chemical research laboratory at the Pittsburgh station, one for deter-

* Communicatd by the Director.

mining the CO_2 content in the air, one for determining CO_2 in flue gases, and one for determining oxygen in air. These are described in Technical Paper 238, "Indicators for Carbon Dioxide and Oxygen in Air and Flue Gas," by L. H. Milligan, D. O. Crites, and W. S. Wilson.

DETERMINATION OF MOLYBDENUM.

By J. P. Bornardi and E. P. Barrett.

DURING the recent activity in the molybdenum market, the methods that have been used for the determination of molybdenum were found inadequate. They were satisfactory for small tonnages of high-grade material, but with the introduction of flotation and the demand caused by the war, the tonnage became so large and the grade of products so low that determination of Mo to the second decimal place was necessary.

The Bureau of Mines, in an investigation recently concluded, has developed improved methods of both volumetric and gravimetric analysis, that are more rapid and accurate than any previously devised.

Among quantitative methods for the determination of molybdenum that are in general use, that of reduction of the molybdenum and titration with potassium permanganate proved to be the most promising and a technic was worked out by which it is satisfactory for rapid, accurate determinations on low-grade ores. In this method the ore is decomposed either by acid or by fusion with Na_2O_2 into a soluble molybdate and insoluble compounds of the other constituents of the ore. The molybdate is filtered, acid added, and the solution is passed through a Jones reductor where the MoO_3 is reduced to Mo_2O_3. The Mo_2O_3 is then titrated with $KMnO_4$, and the percentage of molybdenum present is calculated. Successful use of the method, however, requires close attention to details of procedure.

Gravimetric determination of molybdenum by precipitating and weighing as lead molybdate proved to be rapid and accurate, although certain precautions must be observed. In this method the ore is decomposed with acids and treated with ammonium hydroxide to form ammonium molybdate. From the hot solution the molybdenum is precipitated as $PbMoO_4$ by adding lead acetate solution in 2 or 3 c.c. excess, heating the mixture a few minutes,

and filtering. The precipitated lead molybdate is then ignited, cooled, weighed, and the weight of molybdenum is calculated. Technical Paper 230, of the Bureau, gives details of the methods.

THE PROPERTIES OF STONEWARE CLAYS.

By H. G. Schurecht.

EXPERIMENTS have been conducted by the Bureau of Mines at its ceramic station, at Columbus, Ohio, on the properties of some Ohio and Pennsylvania stoneware clays, with special reference to the possible use of these clays in making chemical stoneware. This work, described in Technical Paper 233 of the Bureau of Mines, was conducted in coöperation with the Ohio Geological Survey, and the Pennsylvania Geological Survey.

From each of the eleven clays tested, a series of seven bodies were prepared, the clay being ground to different grades of fineness and used alone and with varying proportions of feldspar, or feldspar and calcium carbonate added. From those bodies test pieces were prepared which were tested for their pyro-physical properties. The results show a wide range of properties among the different clays tested, and indicate that some of the clays might be used for chemical stoneware.

CASING TROUBLES AND FISHING METHODS.

By Thomas Curtin.

THE BUREAU OF MINES has completed an investigation of casing troubles and fishing methods in oil wells. In the past, many wells have been abandoned because of casing troubles that were thought to be insurmountable, whereas these troubles could have been overcome, had the operator been better informed as to practices and methods employed in other fields, with which he was not familiar. In fields where casing difficulties are of daily occurrence, methods for combatting them have been developed, and if these methods were more widely known and applied wherever the same conditions exist, the oil industry would be greatly benefited. Bulletin 182, of the Bureau of Mines, which presents the results of the investigation, attempts to classify these troubles and suggests solutions that will save the operator discouragement and expense.

Wire Mesh Army Roads in Egypt. T. McLEAN JASPER. (*Engineering News Record*, August 12, 1920, p. 302.)—Loose sand, smoothed and levelled and then covered with chicken netting, firmly pegged down, made roads which gave such good service during the British Army operations in Egypt and Palestine that the method of construction appears to offer possibilities for temporary roads for construction and engineering operations where travel over sand is necessary.

As laid down by the army troops, the best results were obtained with chicken netting of about ¾ in. mesh. This netting, 2½ or 3 ft. wide, came in rolls and four or five rolls placed end to end were unrolled along the route so as to cover a strip about 12 or 15 ft. wide. The joining edges of the netting were fastened together either by clipping on loops of wire at about 3 ft. intervals or by a continuous wire woven in and out of the two edges. At intervals of about 5 ft. the outside edges were pegged down with 1½ in. stakes from 12 to 18 in. long. Roads so constructed were perfectly satisfactory for infantry but were badly damaged if horses or cars were driven over them. The life of these roads is difficult to state; one which had been marched over daily by 3000 to 4000 men was in good condition after six months' use. Other roads, however, failed quite soon. The grade is levelled and smoothed before the netting is laid. No hollows should be left under the netting and the netting should be securely pegged down. As ruts form, the netting is lifted and the sand relevelled. The netting lasts from three to six months, depending on the volume of traffic. Roads of this type are of use only for mechanical transport with pneumatic tires; horse and wheel transport destroy them almost at once.

Castor Oil. (*Engineering World*, August, 1920, p. 100.)—Castor oil figures to a large extent in the manufacture of the artificial leather which takes the place of natural leather in upholstery. It is also an essential component in some artificial rubbers and various kinds of celluloid. The oil furnishes a coloring for butter, and from it is produced the so-called "Turkey red" oil which is an important factor in the dyeing of cotton textiles. One of the largest uses of castor oil is in the making of transparent soaps. The oil also yields sebacic acid, which is employed in the manufacture of candles, and from it is also obtained caprylic acid, which enters into the composition of varnishes peculiarly suitable for the polishing of all kinds of high-class furniture and of carriage bodies. Castor oil is also used in the making of certain waterproof preparations. Most fly-papers owe a large part of their instantaneous action and effectiveness to the fact that the preparation smeared on them largely consists of castor oil.

THE FRANKLIN INSTITUTE.

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NECROLOGY.

Mr. A. R. Shipley, 186 Canner Street, New Haven, Connecticut.

Albert R. Shipley was born at Alpha, Maryland, in 1876, and died in February, 1920. He attended school in Baltimore and later graduated from the McDonough Institute and the Maryland Institute. He was connected with numerous industrial establishments in varous capacities from machinist to engineer. During the Spanish-American War he served as Machinist's Mate and Engineer in the Navy. In 1916 he was called by the Government to the Watertown Arsenal to become Superintendent of Production and continued in this position for sixteen months. The last years of his life he spent as industrial engineer and production superintendent.

Mr. Shipley was a member of the American Society of Mechanical Engineers, the Taylor Society and various other organizations. He contributed papers to the technical societies with which he was connected and frequently took part in discussions. He became acquainted with Mr. Frederick W. Taylor during his connection with the Tabor Manufacturing Company and took a great interest in scientific management; he was recognized as an authority and occasionally delivered lectures on the subject.

Mr. Shipley became a member of the Institute on March, 12, 1913.

Dr. Isham Randolph, 1827 Continental & Commercial National Bank Building, Chicago, Illinois.

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Wilmington Board of Water Commissioners, Annual Water Reports, 1910-1918, inclusive. Wilmington, Del. (From the Commissioners.)

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Yonkers Board of Water Commissioners, Annual Reports, 1901-1913, inclusive. Yonkers, N. Y. (From the Board.)

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BOOK NOTICES.

MÉMOIRES SUR LA RESPIRATION ET LA TRANSPIRATION DES ANIMAUX. Par Antoine-Laurent Lavoisier. 12mo, 68 pages, Gauthier-Villars et cie. 3 fr. in paper.

OBSERVATIONS ET EXPÉRIENCES FAITES SUR LES ANIMALCULES DES INFUSIONS. Par Lazare Spallanzani. Two parts, 12mo, 105 and 122 pages, respectively. Gauthier-Villars et cie. 3 fr. each in paper.

These are two volumes of the series of "*Les Maitres de la Pensée Scientifique*" that the well-known Paris publishing house is issuing, the general

nature of which series was indicated in a review of the first volume. Lavoisier's essay was, of course, originally written in French, so the present issue is merely reprinted from the original memoir, but Spallanzani's memoir was written in Italian, the French text herewith presented being that by Jean Senebier published at Geneva in 1786.

Both essays are interesting. Lavoisier's memoir is well-known to all chemists who have taken interest in the history of the science, as one of epoch-making type, for in it he describes the experiments of heating mercury for a long while in a closed vessel containing air, by which he proved that the formation of the "calx" was due to a direct absorption of a portion of the air, the remaining portion being incapable of supporting combustion of life and being without action on nitric oxide.

Spallanzani's essay is of interest rather to biologists than chemists, but gives a striking picture of the early struggle concerning the nature of generation and reproduction. It is not easy to see why it was divided into two small volumes. It would be an excellent book for a young biologist who has just acquired a reading knowledge of French, for it is written in a very clear style.

HENRY LEFFMANN.

A HISTORY OF CHEMISTRY FROM THE EARLIEST TIMES. By the late James Campbell Brown, D.Sc. (London) LL.D. (Aberdeen). Second edition, edited by Henry Hilton Brown, 8vo. 538 pages, contents, index, portrait and one hundred and six illustrations. Philadelphia, P. Blakiston's Son & Co., 1920.

Histories of chemistry carry us back to a very remote period in human civilization. Modern writers of such works are guided largely by the plan of the great classic in the field, Kopp's "Geschichte der Chemie," now about three-quarters of a century old, but still as important to the student of the subject as is Gibbons' "Decline and Fall" to the student of the history of Europe. Brown follows, substantially, Kopp's system, which divides the early history of chemistry into four periods. Present-day historians are not as strongly inclined to mark off periods as sharply as formerly, regarding the course of events as almost insensibly progressive and not catastrophic.

We are informed in the preface of this edition that it is, except in a few places, a reprint of the first. While it is true that but a little of new has been brought forward in the seven years that have elapsed since the publication of the first edition, it is doubtful if the desire "To preserve Dr. Brown's work as nearly as possible in the shape he wished it to take" is the best service that an editor can render.

So far as the matter of the book is concerned, it is only necessary to say that it is a compact, carefully written and comprehensive account of the history of the science from the earliest recorded date down to a recent period. Some of the most important developments of physical chemistry are left untouched, and the "phase rule" is not found in the index. The style of the text is lively and not infrequently the reader is entertained with a humorous observation. Out of curiosity the reviewer turned to the reference to helium

to see if the author had fallen into one of the numerous pitfalls that seem to beset that element. Sure enough, a glaring error is noted. It is stated (p. 524) that Janssen gave the name to the element causing the peculiar yellow line in the spectrum of the sun's chromosphere! One would suppose that no Englishman would be capable of taking from Lockyer the honor of coining the accepted name for this now famous element.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. The Limiting Velocity in Falling From a Great Height. Report No. 78, Preprint from Fifth Annual Report. 8 pages, quarto. Washington: Government Printing Office, 1920.

This report, by Professor E. B. Wilson, deals with the velocity in falling bombs when the variation in air density with height is taken into account. It is shown that bombs must be dropped from considerable altitudes in order that they may reach a maximum velocity before striking the ground.

Report No. 79. Bomb Trajectories. Preprint from Fifth Annual Report. 10 pages, quarto. Washington: Government Printing Office, 1920.

This report is a mathematical discussion of the trajectories of bombs or projectiles when account is taken of the resistance of the air. It is impossible to express the motion of the bomb exactly so that it must be approximated between two limiting curves whose equation can be expressed. It is found that the trajectory in ordinary cases is not far from a parabola, and with an initial velocity of 200 feet per second and a terminal velocity of 800 feet per second in a drop of 2000 feet the correction can be determined to within 15 feet.

Report No. 81. Comparison of U. S. and British Standard Pitot-Static Tubes. Preprint from Fifth Annual Report. 8 pages, plate, quarto. Washington: Government Office, 1920.

British and United States standard Pitot tubes were placed in the reduced section of the Navy Yard 8 foot tunnel and the heads for each tube were determined for speeds from 20 to 160 miles per hour. In order to be sure that the velocity was the same at the positions at which the Pitot-Static tubes were placed, after the first run the position of the tubes was reversed and a second run made. It was found that the two tubes checked with one another within the precision of the measurements and gave a true Pitot reading.

Report No. 86. Properties of Special Types of Radiators. 16 pages, illustrations, plates, quarto. Washington: Government Printing Office, 1920.

The report discusses the general performance characteristics of three special classes of radiators: Those with flat-plate water tubes, fin and tube types and types that whistle in an air stream. Curves and tables show the performance of representative radiators of each class, and compare the flat plate and whistling types. Empirical equations are given for estimating the performance of flat-plate radiators of various dimensions.

The report also contains a brief discussion, with curves showing effect of yawing on the properties of a radiator.

PUBLICATIONS RECEIVED.

Text Book of Aero Engines, by E. H. Sherbondy, consulting engineer, and G. Douglas Wardrop, managing editor of *Aerial Age Weekly.* 363 pages, illustrations, quarto. New York, Frederick A. Stokes Company, 1920.

Motion Study for the Handicapped, by Frank B. Gilbrith and Lillian Moller Gilbrith, Ph.D. 165 pages, illustrations, plates, 8vo. London, George Routledge and Sons, Ltd., 1920. New York, E. P. Dutton & Company. Price, $4 net.

National Conference on Concrete House Construction: Proceedings held at Auditorium Hotel, Chicago, February 17, 18, and 19, 1920, edited by the Secretary, 235 pages, illustrations, 8vo. Chicago, Published by the Conference, 1920.

Bureau of Standards: Circular No. 92, Operation and Care of Vehicle-type Batteries, 94 pages, illustrations, plates, diagrams, 8vo. Washington, Government Printing Office, 1920. Price, 30 cents.

Bureau of Mines: Bulletin 173, Manganese Uses, Preparations, Mine Costs, and the Production of Ferro-alloys, by C. M. Weld and others. 209 pages, 8vo. Technical Paper 229. Accident Prevention in the Mines of Butte, Montana. 59 pages, plate, 8vo. Technical Paper 244, Use of Stenches as a Warning in Mines, by S. H. Katz, V. C. Allison, and W. L. Egey. 31 pages, illustrations, plate, 8vo. Washington, Government Printing Office, 1920.

Royal Institution of Great Britain: Weekly Evening Meeting. January 31, 1919, Giant Suns, by H. H. Turner, D.Sc. 10 pages. February 14, 1919, The Propagation of Earthquake Waves through the Substance of the Earth, by Cargill G. Knott, D.Sc. March 14, 1919, The Organ of Hearing from a New Point of View, by Arthur Keith, M.D. 4 pages. January 30, 1920, The Gyrostatic Compass, by Sidney G. Brown, F.R.S. 21 pages, illustrations. February 20, 1920, British Crop Production, by Edward J. Russell, D.Sc. 14 pages. March 12, 1920, String Figures, by W. W. Rouse Ball, 34 pages, illustrations. April 30, 1920, The Earliest Known Land Flora, by F. O. Bower, Pres. R. S. E. 10 pages, plates. May 21, 1920, The Thermionic Valve in Wireless Telegraphy and Telephony, by J. A. Fleming, D.Sc., 29 pages, illustrations. June 4, 1920, Science and Poetry, by Col. Sir Ronald Ross, 22 pages. Nine Pamphlets, 8vo. London, The Royal Institution, 1919 and 1920.

National Advisory Committee for Aeronautics: Technical Notes No. 8, Duralumin, by E. Unger and E. Schmidt, translated from *Technische Berichte,* vol. iii, Section 6, by Starr Truscott, 10 pages, plates. No. 9, Theory of Lifting Surfaces, Part I, by L. Prandtl, translated from the German and abstracted by W. Margoulis, 11 pages. No. 10, Theory of Lifting Surfaces, Part II, by L. Prandtl, translated from the German and abstracted by W. Margoulis, 10 pages. Three pamphlets, quarto. Washington Committee, 1920.

CURRENT TOPICS.

Standardized Lumber Sizes Means. (*U. S. Forest Products Laboratory, News Note.*)—The need of standard sizes for all the different lumber products has been felt for some time and the action of prominent lumbermen in promoting standardization presages another progressive step in the lumber industry. The laboratory has been coöperating during the past year with the National Lumber Manufacturer's Association in working out an equitable basis for standardizing softwood lumber sizes. Some of the benefits to be derived from the standardization of sizes are as follows:

1. It makes possible a common language for all. The consumer can substitute one species for another with assurance of getting material of the same size. Similarly, if a contractor starts to build several houses and orders his millwork, sash, doors, etc., based on certain lumber sizes as to stock around which the casing fits, the kind of wood can be varied as he desires.

2. Architects and purchasers can order more rapidly with one set sizes.

3. Material of standard sizes is more salable.

4. Building design is simplified, since fewer sizes can be used.

5. Uniformity in construction results, regardless of the grading rules under which the material is purchased.

6. Remanufacture of larger sizes to match smaller sizes will be reduced and greater utilization with less labor and expense result.

7. Standardization of sizes eliminates local legislation on lumber sizes which confuse manufacture and distribution. Such legislation has been already suggested.

8. Standardization makes for fewer sizes and hence greater efficiency, ease and accuracy in lumber grading.

9. It equalizes competition between manufacturers, because present differences in overrun and freight charges are important factors in determining price.

10. It makes possible uniform practice and sizes in resawing.

11. It makes possible a fewer number of drying schedules in the kiln drying of lumber.

The National Lumber Manufacturer's Association will meet September 28th and 29th in Chicago, at which time action will be taken on the standardization of sizes for all softwood lumber.

Pulp and Paper Manufacture. (*U. S. Forest Products Laboratory, News Note.*)—There are four general processes of reducing wood to a pulp condition. They are known as the ground wood, sulphite, sulphate and soda processes of pulping.

The ground wood process of pulping is used mainly for the

reduction of non-resinous, long-fibred woods, such as spruce and balsam. The barked wood in 2-foot lengths is ground on a grindstone, the surface of which has been sharpened to produce a cutting action. The yield of pulp is approximately 90 per cent. of the weight of the raw wood. The pulp is inferior in quality and is used only to mix with longer- and stronger-fibred stock—such as unbleached sulphite pulp—in the manufacture of paper in which permanency is not required.

The sulphite process is used chiefly for the reduction of long-fibred, non-resinous, coniferous woods, such as spruce, balsam and hemlock, giving a yield of less than 45 per cent., based on the weight of the original wood used. This pulp can be bleached to a high degree of white and is largely used both unbleached and bleached in the manufacture of books, newsprint, wrapping, bond, and tissue papers.

The sulphate or kraft process of pulping is used for the reduction of any long-fibred wood and yields approximately 45 per cent. This is an alkaline process and can be used for the reduction of both resinous and non-resinous woods, such as the pines, spruces, hemlocks, firs, etc. Kraft pulp is normally not bleached; but on account of its strength it is used for the manufacture of kraft wrapping paper and high test container board.

The soda process is restricted in use to the short-fibred deciduous woods, such as aspen, cottonwood, willow, gum woods, etc., yielding less than 45 per cent. The resulting pulp is invariably bleached to a high degree of white, and after admixture with a longer- and stronger-fibred stock, such as spruce sulphite, is used for the manufacture of book, lithograph, envelope papers, etc.

Mountains in Idaho. (*U. S. Geol. Survey Press Bulletin No. 454,* August, 1920.)—Hyndman Peak is the only named mountain in Idaho that rises above 12,000 feet. It stands near the Blaine–Custer county line and has a height of 12,078 feet. There are, however, several unnamed peaks near Hyndman Peak whose elevations are greater than 12,000 feet, as shown by the contours on the Hailey topographic map, published by the Survey.

Highest Mountain of Guam. (*U. S. Geol. Survey Press Bulletin No. 454,* August, 1920).—Guam, our little Pacific Island possession, is a mere speck in the "South Sea," as Balboa called the Pacific Ocean, but it is by no means flat. Jumulong Mangloc, the highest point in the island, stands 1,274 feet above the sea, according to a chart published by the Survey.

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